

THE MODERN PLUMBER & SANITARY ENGINEER



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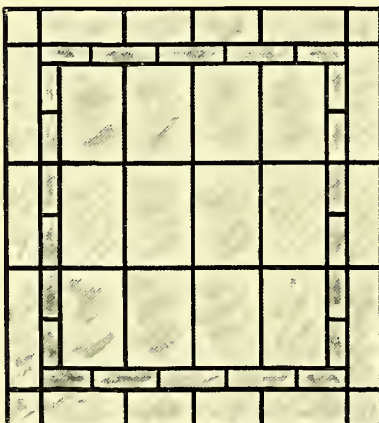
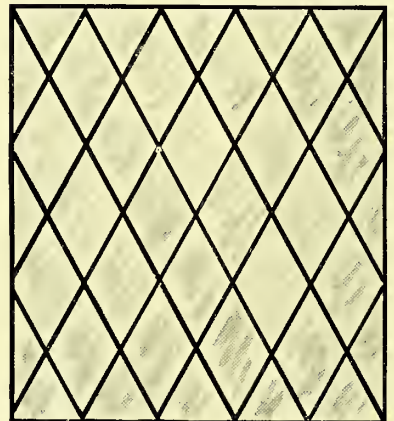
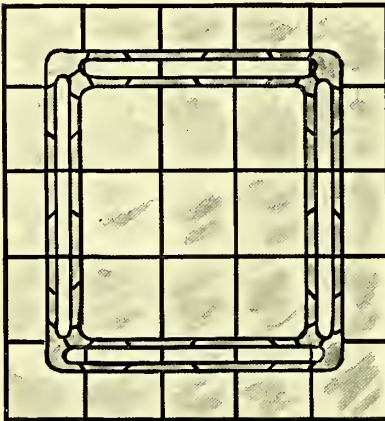
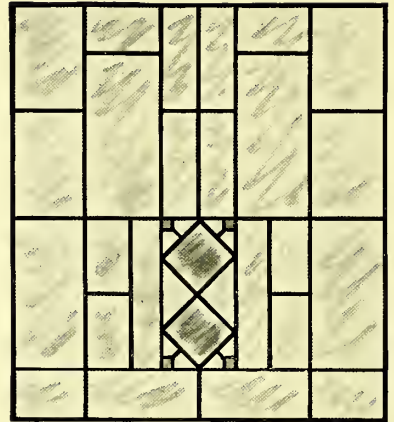
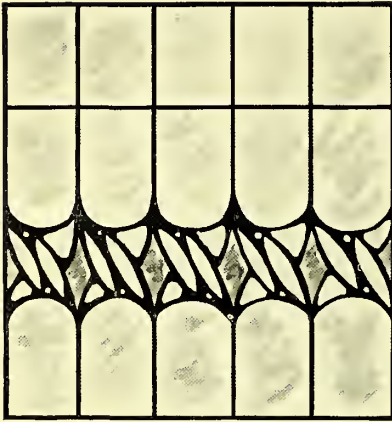
James Mahanwood



THE
MODERN PLUMBER
AND SANITARY ENGINEER







EXAMPLES OF LEADED GLAZING

(Messrs. Weldon & Co., Croydon)

THE MODERN PLUMBER AND SANITARY ENGINEER

TREATING OF PLUMBING, SANITARY WORK, VENTILATION, HEATING (ELECTRIC AND OTHER), HOT-WATER SERVICES, GAS-FITTING, ELECTRIC LIGHTING, BELL-WORK, GLAZING, &c.

BY SIXTEEN SPECIALIST CONTRIBUTORS

UNDER THE EDITORSHIP OF

G. LISTER SUTCLIFFE

A.R.I.B.A., M.R.S.I.

Editor of "The Principles and Practice of Modern House Construction", &c.

WITH APPENDICES OF
TABLES, MEMORANDA, MENSURATION, ETC.

*ILLUSTRATED BY ABOUT ELEVEN HUNDRED FIGURES IN THE
TEXT AND ABOUT FIFTY PLATES, MANY OF THEM IN COLOUR*

DIVISIONAL-VOL. V

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Member of the North-East Coast Institution of Engineers and Shipbuilders;
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ELECTRIC LIGHTING AND HEATING

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SECTION XI

ELECTRIC LIGHTING AND HEATING

CHAPTER I

ELECTRIC CURRENT AND INCANDESCENT LAMPS

In wiring premises for electric light, where the number, positions, and candle power of the lights have been decided upon, it is of the first importance to so arrange the circuits and the number of lights upon each branch that uniformity in the size of branch wires, sub-mains, and fuses, and general convenience and safety may be secured. At the same time the various wires and cables used must be of sufficient size to carry the currents without heating or undue loss of pressure. In dividing up the lights there are various considerations to be taken into account. To comply with insurance rules no branch circuit must carry more lamps than can be controlled by a 5-ampere fuse, and this is advisable also from the point of view of convenience, as in the event of a fuse blowing, a small number only of the lights will be extinguished. Sometimes there are special requirements of the owner or tenant to be taken into account, such as the arrangement of certain portions of the lighting on separate meters, or special requirements as regards switching.

Current.—As the sizes of wires depend upon the current carried, it should be well understood how to sum up the currents required by lamps in any specific case. The current taken by any lamp depends upon its candle power and the pressure of the supply. The higher the pressure the less the current for a certain candle power; also, the higher the candle power the larger the filament and the greater the current required to incandesce it at any given pressure. On the other hand, whatever the pressure, the current can always be found by remembering the number of watts of electric power necessary to produce 1 candle power of light in any particular lamp. The power in watts is the product of current in amperes and pressure in volts, or in other words amperes multiplied by volts gives power in watts. Hence the current taken by lamps of any particular candle power can be calculated very readily by dividing the number of watts by the voltage of the supply.

The ordinary carbon-filament lamp (fig. 753) with clear globe takes $3\frac{1}{2}$

to 4 watts per candle. Lamps taking $2\frac{1}{2}$ watts only per candle in clear globes without reflectors can be obtained, especially in high candle powers, but the useful life is not so long with a high-efficiency filament.

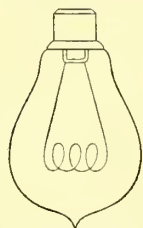


Fig. 753.—Carbon-filament Lamp

One	8-candle-power lamp takes 30 to 35 watts.				
"	16	"	"	60	"
"	32	"	"	120	"
"	50	"	"	175	"
"	100	"	"	250	"

Dividing the number of watts by the voltage of the supply, we obtain the following results:—

TABLE I.—CURRENT TAKEN BY CARBON-FILAMENT LAMPS.

					At 100 Volts.	At 200 Volts.	At 240 Volts.
One	8-candle-power lamp takes ...				0.35 ampere	0.17 ampere	0.15 ampere
"	16	"	"	"	0.6 "	0.3 "	0.25 "
"	32	"	"	"	1.2 "	0.6 "	0.5 "
"	50	"	"	"	1.75 "	0.87 "	0.73 "
"	100	"	"	"	2.5 amperes	1.25 "	1.04 "

In an installation of (say) 40 lamps of 8-candle power, 20 of 16-candle power, 15 of 32-candle power, 10 of 50-candle power, and 4 of 100-candle power, the total current and the sizes of the main cables (at 1000 amperes per square inch) at each voltage would be—

72 amperes at 100 volts,	19/15 mains.
36 " " 200 "	7/14 or 19/18 mains.
30 " " 240 "	7/15 mains.

It will be seen that the currents and the mains required are very different at different voltages.

Nernst lamps (figs. 754 and 755) are more efficient, light for light, than carbon-filament lamps, and have the advantage of showing less fluctuation with variations in pressure. The A and B models when new take only 1.7 watt per candle in small sizes to 1.5 in large sizes. The Brilliant or Luna type of the Nernst lamp has a flat burner designed to throw an intense light in a downward direction. Taking the candle power obtained over the lower half sphere, this lamp takes under 1 watt per candle. A $\frac{1}{4}$ -ampere 200-volt B Nernst lamp takes 50 watts and gives 30 candle power, whereas a carbon lamp of 32-candle power takes 120 watts or rather more than double the power. Nernst lamps, however, can only advantageously take the place of carbon lamps in comparatively large spaces where good diffusion of light is required. Wherever light at specific points is wanted, such as over desks, tables, workshop benches, &c., it is more economical to use 8- or 16-candle-power carbon lamps fixed near the work. In restaurants and the like one 132-candle-power 1-ampere A pattern

Nernst lamp replaces with much improved diffusion about 20 ordinary 8-candle-power lamps at less than half the cost for energy.

Nernst lamps must be carefully selected for voltage, as if much overrun the life is shortened. Even the rises in pressure on supply mains at times of light load affect the durability of the lamp, and it is desirable to use lamps somewhat under the voltage of supply. The voltage marked on the replacement piece carrying the glower and heater is that taken by the glower alone, and the voltage of the lamp is the sum of the volts marked on the replacement piece and the resistance tube. For instance, the lamp suited to a 200-volt supply would have 180 volts marked on the burner and 20 volts on the resistance tube.

The working parts of the Nernst lamp are shown in fig. 754. Current passes from the positive terminal to the automatic cut-out, and thence by the fixed stop in contact with the movable lever or armature of the electro-magnet to the heater spiral surrounding the filament. The latter is a short straight yellow wire composed of the rare earth zirconia, which is only consumed at a very slow rate when raised to a white heat in air. Consequently the air does not require to be exhausted from a Nernst lamp globe, as it does in a carbon-filament lamp. The burner of the Nernst lamp can therefore be replaced when it gives out, all other parts of the lamp being permanent and not in the ordinary course requiring renewal. The filament when cold will not conduct an electric current, and the heater spiral surrounding it is provided for the purpose of raising its temperature sufficiently to render it conducting, after which the heater is automatically cut out. In the illustration it will be noticed that, as soon as the filament becomes conductive, current passes to it through the cut-out coil and the buffer resistance. Consequently the armature of the electro-magnet is attracted and breaks the connection with the fixed stop, thus cutting off current from the heater. About 10 seconds generally suffice to raise the temperature of the filament to the point of conductivity, but lamps not suited to the voltage, or old lamps, may take 30 seconds or more to light up.

Carbon-filament and Nernst Lamps Compared.—Some consumers suffer considerably from the fluctuating pressure maintained by the supply company from which they obtain current. Carbon-filament lamps show any variations in pressure in a very marked degree, and nothing gives a poorer lighting effect than orange-coloured filaments. The absence of fluctuation in light in the Nernst lamp, due to variations of pressure, is obtained by the resistance of iron wire included in circuit with the glower. This resistance acts as a buffer or compensator. On a rising pressure the current through the resistance wire and filament tends to increase, but is checked by the rise in resistance of the iron wire due to its increasing

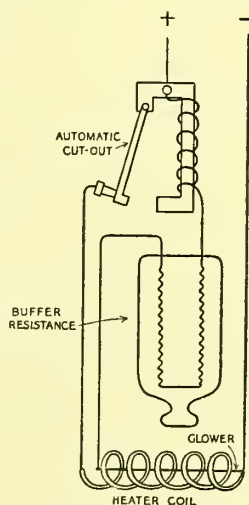


Fig. 754.—Nernst Lamp Connections

temperature. The reverse effect takes place on a falling pressure, and by this means the lamp is automatically compensated. On the other hand, both the glower and the heater in the Nernst lamp are very fragile, and necessitate much greater care in handling than carbon-filament lamps. The lamps are not suited for situations subject to vibration or jar, nor for positions where the light is required to be frequently switched on and off. The time taken in lighting up, from the moment of switching on, in some cases is immaterial, whilst in others it would be objectionable. But where it is convenient to have some carbon-filament lamps as well, say round the sides of a room, with Nernst lamps in the centre, this objection does not hold.

Combination Lamps.—An ordinary carbon incandescent lamp may be connected to a Nernst lamp in such a way that the former is lighted immediately on switching on, and automatically cut out when the Nernst lights up. This can be done by connecting the carbon lamp between the fixed contact of the automatic cut-out and the negative terminal of the Nernst lamp. The carbon lamp is then disconnected by the action of the cut-out at the same moment as the heater coil of the Nernst is cut out. The Express Nernst lamp is arranged in this way with two auxiliary carbon lamps for lighting up instantaneously.

Direct and Alternating Currents.—Nernst lamps are made for direct current with any voltage between 100 and 300, and for alternating current with a voltage between 200 and 300. Only direct-current lamps should be used on direct-current circuits, and when fixing them it must first be found out which poles of the lampholders are positive and negative respectively. The lamps must then be put into their holders the right way, and this point must be attended to every time lamps are temporarily removed and replaced. Where a Nernst lamp is wired to a wall plug, the same care must be observed in putting the plug into the socket, and the plugs should be marked at the top for this purpose, or so constructed that they can only go in one way, as, for instance, with a concentric plug. If the direction of current is accidentally reversed the lamp will continue to burn, but its life will be considerably shortened.

Varieties of Nernst Lamps.—These lamps are intended to burn hanging downwards. In most cases they will burn satisfactorily if fixed upwards, but the cut-out movement does not admit of this in some patterns, especially in the larger sizes. There are three patterns of burner made. Type B (spherical) for small lamps, type A (spherical) with vertical burner, and the Brilliant (hemispherical) with flat burner. The following are the usual ranges of voltage current and candle powers of each:—

Type B, $\frac{1}{4}$ ampere	100 to 250 volts,	18 to 40 candle power.
" " $\frac{1}{2}$ "	100 " 150 " "	28 " 46 " "
" A, $\frac{1}{2}$ "	200 " 250 " "	66 " 84 " "
" " 1 "	100 " 250 " "	59 " 168 " "
Brilliant, $\frac{1}{2}$ "	200 " 250 " "	110 " 142 " "
" 1 "	100 " 250 " "	105 " 284 " "
" 2 "	100 " 150 " "	210 " 314 " "

An A type lamp with waterproof cover and swivel hook, suitable for

outdoor lighting, is shown in fig. 755. In the Multiple lamp three A or Brilliant lamps are combined in a ceiling fitting, with large semicircular frosted globe and ornamental metal top. These combination fittings, of course, burn singly on any voltage, and a large candle power is obtained up to 800 or more, comparable with that of an arc lamp.

The Tantalum lamp (fig. 756) is a metallic-filament lamp which is coming largely into use in towns having a direct-current supply. As it is not yet made for voltages above 125, two or three lamps have to be connected in series according to the pressure available. They are used to advantage in situations requiring groups of lamps, and are made in two efficiencies, 1·7 and 2·2 watts per candle power.

Considering the useful life as the period taken to reduce the light by 20 per cent, the life of the lamps taking 1·7 watt per candle is 400 to 600 hours, and that of the 2·2 watts lamp 800 to 1000 hours.

The advantages which this lamp possesses are the whiteness of the light it gives, and its adaptability for burning in any position without adversely affecting the filament. The first cost of tantalum lamps is about three and a half times that of a carbon lamp, but the consumption of current is less than half that of carbon lamps giving the same amount of light.

The economy or otherwise in the use of tantalum lamps depends therefore as much upon the cost per unit for electricity as upon the life of the lamps. The true cost of a lamp is the sum of the costs for renewals and consumption, and comparisons of costs must of course be made upon equal

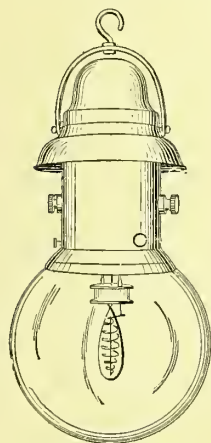


Fig. 755.—Nernst A Lamp with Waterproof Cover and Swivel Hook for Outdoor Lighting

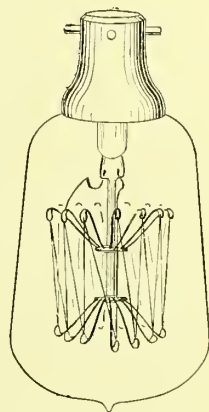


Fig. 756.—Tantalum Lamp

candle powers, that is, light for light. The tantalum lamp shows to greatest advantage as regards economy when the cost of supply is high.

For example, take a town with 200 volt D.C. supply at 4*d.* per unit. In a shop window, let us say, points of 40-candle power are required. We may put in for each point two 100-volt 21-candle tantalum lamps in series or three 200-volt carbon lamps (two of 16-candle power, and one of 8-candle power). Assuming the tantalum lamps to have half the life of the carbon lamps, the latter would cost about £1 per 1000 hours more than the former. Of course at any higher cost than this per unit, tantalums would show to still greater advantage. At 2*d.* per unit the advantage almost disappears, and at 1½*d.* per unit the cost of the two kinds of lamps is about the same. If the life of tantalum lamps were only one-third that of carbon lamps, the costs would be equal at about 2*d.* per unit, and carbon lamps would be more economical when the cost of current was under 2*d.* per unit, while tantalums would be more economical when the cost exceeded 2*d.* per unit.

The Osmium lamp (fig. 757) is another instance of a new form of metallic-

filament or wire lamp. These lamps should only be burned in a vertical hanging position. They are made in voltages up to 75, and are used three or more in series according to the voltage. They take 1.5 watt per candle, and have therefore more than double the efficiency of the ordinary carbon lamp, but the life is not so reliable. They are known in the trade as "Osmi" lamps. A great feature of the osmium, tantalum, and other wire lamps is that the globes do not blacken, although the light falls off slightly with age. Also, variations in voltage do not cause anything like the fluctuations in light noticeable in carbon-filament lamps. The useful life of osmium lamps is given as over 1000 hours. Special group holders for four or five lamps in series are made for the usual voltages. There is, of course, the disadvantage in lamps connected in series that if one lamp fails, all those in the group go out too. This is righted by putting in a new lamp, but the group is not always readily accessible, and delay occurs.

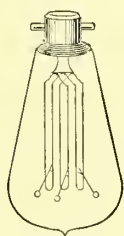


Fig. 757.—
Osmium Lamp

The Tungsten or Wolfram Lamp.—New lamps are now being put on the market, in which the filament is composed partly or wholly of the metal Tungsten or Wolfram. They go under various trade names, such as "Osram" and "Osmin". Their properties are similar to those of the "Osmium" and "Tantalum" lamps, but it is claimed that they can be made for pressures of 200 volts. The filaments are very fragile, and it is advisable to use these lamps, for the present, in positions

where there is an absence of vibration.

For **independent installations** up to a few hundred lights, such as those for country houses, institutions, and the like, the usual voltage is 100 to 110, on account of keeping down the number and cost of accumulators. At this voltage metallic-filament lamps may be used in all positions where a good light is required. For example, on an installation of 250 lights, about 50 lights may be required for passages, servants' rooms, stables, &c., where 8-candle lamps are most suitable. In all other parts more light per point is necessary, and in the ordinary way 16-candle lights would be used. If all these were carbon-filament lamps, the load with two-thirds of the lights on at one time would be a little over 9 kilowatts (9 K.W.) By using tantalum lamps for the higher candle powers, the load under the same conditions would be only $5\frac{1}{2}$ K.W., or a little more than half. Thus the installation might consist of 50 carbon lamps of 8-candle power, 120 tantalums of 13-candle power, and 80 tantalums of 21-candle power. The higher-candle-power lamps would be used in positions where a superior light was desirable, but not always in use, such as the billiard room, library, and some reception rooms. The accumulators for keeping two-thirds load going for (say) ten hours would be much larger if all the lamps were carbon, namely, 54 cells of 920 ampere-hours capacity, whereas with tantalums a capacity of 550 ampere-hours would suffice. The 21-candle-power tantalum lamp takes about the same current as the 8-candle-power carbon lamp at 100 volts, but it is only in certain positions that so large a unit of light is desirable, and there are many places where an 8-candle-power lamp is more suitable. For these positions it is much better to use the 8-candle-

power carbon lamp, on account of its less cost as well as its more suitable light. The extra initial and renewal costs of tantalum lamps must be considered in each particular case in relation to the saving in accumulators and fuel, and the improvement in the amount and quality of the light.

Other new lamps are the ordinary carbon-filament lamps mounted in 4-in. or 5-in. spherical bulbs, obscured at the lower part, and having a conical reflector at the top. The various kinds are known by trade names, such as the Robertson Wytelite lamp of the General Electric Company (fig. 758), the Radiolite lamp of the Edison & Swan Company, the Meridian lamp of the British Thomson Houston Company, the Exelite lamp of Messrs. Gabriel & Co., the Outshine lamp of the Sunbeam Lamp Company, the Snowilite of Messrs. Philips & Co., the Supreme lamp of the Britannia Electric Lamp Works, the Electralite of Messrs. Falk Stadelmann & Co., &c. The advantage of these lamps is that the globes, being large in comparison with the size of filament, do not blacken with age to the extent that those of ordinary lamps do. The light is also concentrated and directed downwards by reflection, and the illumination on the work immediately below the lamp is much greater than with the ordinary lamp. They are therefore specially applicable in suspended positions. The efficiencies claimed are 2 to $2\frac{1}{4}$ watts per candle.

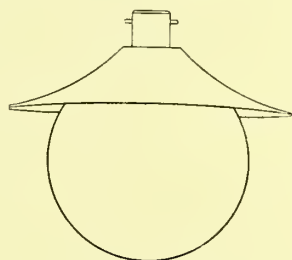


Fig. 758.—Robertson Wytelite Lamp

The Tantalum Sun lamp is another example of a 4-in. bulb lamp with special reflector giving 45 candle power at 110 volts and taking 76.5 watts. In a downward direction the light is about 180 candle power, giving the remarkable efficiency of .45 watt per candle. The reflector is of holophane glass carried on a gallery. The useful and total life of this lamp is claimed to be appreciably longer than that of the smaller-bulb tantalum lamps.

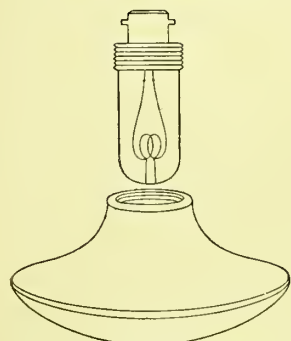


Fig. 759.—The Reflex Lamp and Reflector

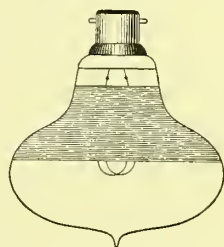


Fig. 760.—Conical Silvered Lamp

The Reflex lamp, brought out by the Britannia Electric Lamp Company, has a specially shaped and silvered reflector, which concentrates and directs the light so as to produce 80 candle power in a downward direction from an ordinary filament consuming 68 watts. The lamp (fig. 759) is tubular in form, and is fixed inside the reflector by means of a screwed cap attached at the top. Above this the ordinary brass cap is fitted for fixing to a bayonet socket. The authors have tested this lamp on the photometer, and found the above claim of .85 watt per candle perfectly correct, taking the candle power over the lower hemisphere. This marks an advance in the attempts which are being made to increase

the illuminating effect of carbon-filament lamps by means of specially designed reflectors.

Another form of reflector lamp largely in use is shown in fig. 760. This has a bulb of special shape, the top of which is silvered so as to form a conical reflecting surface. It is one of the various forms of I.E. reflecting glow lamps brought out by the Improved Electric Glow Lamp Company, Ltd. The lamp is known as "Conical silvered", and is used for shop-window lighting, where a good light is required to be projected in a downward direction.

CHAPTER II

WIRES FOR BRANCH CIRCUITS AND MAINS

Branch Circuits.—The current on a branch circuit of lamps must be controlled by one fuse on each pole, and must not by all accepted rules exceed 3 amperes. Some supply authorities stipulate for $2\frac{1}{2}$ amperes only. The reason for this is that each branch can be controlled by a 5-ampere fuse (a No. 24 or 26 fuse wire), which is supposed to protect the smallest wire—that is to say, if a "short" happened on a "flexible", it would generally blow this fuse before any serious burning occurred on the covering of the flexible. It cannot be said, however, that this can always be relied upon. Shorts are not always "dead", or straight from one conductor to the other, but may be partial, where the leak between the conductors is small or gradually increasing; in such a case it is possible for the covering of a flexible to be set smoking before the fuse blows.

Flexible Wires.—It is for this reason that flexibles should never be fixed to walls, woodwork, or fittings of an inflammable material, not even with insulated staples. In fact a flexible must be regarded and used solely as a portable connection to a portable fitting. The fixing of flexibles outside metal fittings, such as ornamental brackets, piano sconces, &c., is an admissible exception to this rule, but of course in these cases the fittings must be entirely of metal or other incombustible material. Where a wall plug has been put in, and the furniture afterwards arranged, it sometimes happens that the table or desk where the portable lamp is wanted is at the other end of the room, and the flexible is inconveniently long for lying loose. In cases like this flexibles are frequently stapled up along the skirting boards or picture rails, a practice which is very dangerous and not allowed by insurance rules. What should be done is to extend the wiring in casing or conduit to a plug in the new position, near the table where the lamp is to be used, so that only a short length of flexible is necessary, which can be left quite loose and free.

Number of Lamps on Branch Circuits.—To keep to the 3-ampere rule the lamps on each branch circuit must not exceed a certain number, and this number depends upon their candle power and the voltage of the supply. The current taken by lamps of different voltages has been given in

Chapter I, and if the maximum current of 3 amperes is divided by the current per lamp, this will give the number of lamps of that particular candle power that can be wired together on one fuse way. For instance, at 200 volts a 16-candle-power lamp takes .3 ampere, and the number of these lamps for a total of three amperes is $3 \div .3 = 10$. In the same way the number of 8-candle-power lamps is $3 \div .17 = 18$.

The following list gives the number of carbon-filament lamps of ordinary size and usual voltages which may be wired on one branch circuit:—

At 100 volts, 9 lamps of 8-candle power, or 5 of 16-candle power.

At 200 volts, 18 lamps of 8-candle power, or 10 of 16-candle power.

At 220 volts, 19 lamps of 8-candle power, or 11 of 16-candle power.

At 240 volts, 20 lamps of 8-candle power, or 12 of 16-candle power.

It is seldom necessary or convenient to put on one circuit the full number of lamps that are allowed, for if the fuse blows a good many lights are extinguished; but the above figures should be kept in mind or handy for reference, as, when a number of lamps and clusters in different rooms are run together, the number may be otherwise exceeded.

Sizes of Branch Wires.—A 3/22 wire is allowed by the rules of the Institution of Electrical Engineers for a 3-ampere circuit, but it is better in cases where there are long runs, or where the number of lamps is near the maximum, to use 3/20 wire, so as to minimize the drop in voltage. Even 7/22 may sometimes be necessary. In a branch circuit one size only of wire should be used. In any group of lamps looped in parallel the wire nearest the feeding-point carries the whole current to the group, while the wire at the distant end carries only the current for one lamp. Where each successive lamp is taken off, the current is reduced on the remaining portion of the branch wires. On this account sometimes two sizes of wire are put in on one branch circuit, but this is not good practice nor advisable for a circuit controlled by one pair of fuses only.

Pressure Drop.—There is always some voltage expended in a wire carrying current, the exact amount of which depends upon the size and length of wire and the current carried. For example (say) a pair of 7/16 sub-mains is run between a switchboard and a distribution box, the length of run¹ being 20 yd. Suppose the distribution box supplies nine $2\frac{1}{2}$ -ampere branch circuits. If all lights are on, the total current is $9 \times 2\frac{1}{2} = 22\frac{1}{2}$ amperes, and when carrying this current the 7/16 cable uses up 1 volt. Consequently the voltage at the switchboard must be 101 to maintain 100 at the distribution box. There will be a further loss of voltage on the branch wires. This loss is known as the “drop” on the wires. If only half the lights are on, the current is halved and the voltage loss becomes halved; in fact, the loss on the mains is proportional to the current for a given size and length of cable. It is also proportional to the size and length of the cable for a given current carried. In other words, the drop would be reduced to half by using (1) half the

¹ A run is understood to mean a pair of cables, the actual length of cable being twice the length of the run.

current, or (2) mains of twice the sectional area, or (3) mains of half the length.

These three conditions can be simplified down to two by combining the first two, the current and the sectional area of the conductor, and using the term *density* to denote the current per square inch of conductor area. For example, the drop is the same (for the same length) in all of the following:—

A conductor of $\frac{1}{16}$ sq. in. sectional area carrying 100 amperes.					
"	"	$\frac{1}{4}$	"	"	250
"	"	$\frac{1}{2}$	"	"	500
"	"	1	"	"	1000
"	"	2	"	"	2000

The density is found by dividing the current by the sectional area of the wire, and it will be noticed that, in all the above cases, the current divided by the area gives 1000 as the density—that is 1000 amperes per square inch area. The density in all these cases being the same, the voltage drop is also the same in each size of conductor for a given length. Hence it is very convenient to reckon the drop by the density. For instance, at a density of 1000 the drop is 1 volt per 20 yd. run of double conductor. In the example given above of a $\frac{7}{16}$ sub-main carrying $22\frac{1}{2}$ amperes, we have an instance of a density of 1000 amperes per square inch, for the area of a $\frac{7}{16}$ conductor is $\cdot 0223$ sq. in., and the density is $22\cdot 5 \div \cdot 0223$, which is practically 1000. On a run of 20 yd. at this density the drop is 1 volt. At a lower density conductors of the same size can be run a greater distance for the same drop.

It is useful to remember that there is 1 volt drop for every 20 yd. run at 1000 density, 25 yd. run at 800 density, 33 yd. run at 600 density, 40 yd. run at 500 density. In other words, the number 20,000 divided by the density gives the number of yards run per volt drop.

Sizes of Mains.—From the explanation already given it will be seen that the higher the pressure of supply the less the size and cost of conductors required for the mains. It is in the mains of the supply authority that the full advantage of this economy is secured, but it is also apparent in the size and cost of mains and sub-mains in installations of any size. Where the mains have to be run for a considerable distance from the point of supply to the main switchboard, or where the sub-mains have to be run for some distance from the board to the distributing boxes, from which motors and lights are fed (as is frequently the case in mill, factory, or shipyard work), the saving on these items with the higher voltage is considerable. The mains and sub-mains in an installation should be of such a size that the pressure at the most distant lamps, when all are alight, is not more than 2 volts lower than the pressure at the supply terminals. If smaller mains than this are used, there will be an objectionable fluctuation in the light when a portion of the lighting is switched on or off.

In Table II are given the sizes of conductors most commonly in use, and the currents they carry at various densities.

TABLE II

Size of Conductor, S.W.G.	Current in Amperes at Densities of		
	1000	800	600
7/20	7	5½	4
7/18	13	10	8
19/20	20	16	12
7/16	23	18	14
19/18 or 7/14	35	28	21
19/17	46	37	28
19/16	62	50	37
19/15	76	61	46
37/17	90	72	54
19/14	97	78	59
37/16	122	97	73
19/12		132	99
37/14		153	115
Corresponding to	20 yd. run per volt	25 yd. run per volt	33 yd. run per volt

In conductors smaller than 7/18, densities over 1000 are allowed, because wires of small diameter radiate the heat more quickly, and proportionately greater currents can be used for the same limit of temperature rise. Moreover, branch wire runs are not generally very long, and therefore the drop on them is small.

The currents allowed by the Institution of Electrical Engineers for wires in casing or conduit, and also those commonly allowed in practice, are given in Table III.

TABLE III

Size of Wire, S.W.G.	Current Allowed by Inst. Elec. Engineers' Rules.	Usual Maximum Current in Practice.	Density.	Yards run per Volt Drop for Current used in Practice.
	Amperes.	Amperes.		
18	3·1	3	1700	12
3/22	3·3	3	1800	11
3/20	4·8	4	1300	15
16	4·9	4	1250	16
7/22	6·2	4½	1060	19
7/21½	7·0	5	1020	19

As an example, take an installation of 180 16-candle-power 100-volt lamps. Each fuse box feeds (say) six branch circuits of five lamps each (3 amperes per branch, 18 amperes per box). Taking 5 yd. run as the distance of the farthest lamp from these boxes, and using 3/22 wire, the drop on the branch wires will be ½ volt, as, according to Table III, a run of 11 yd. causes a drop of a volt on this size of wire, with a current of 3 amperes. The wiring from all the fuse boxes (six in all) will come into a switchboard, and from this point there will be one pair of mains to the dynamo, if it is a

self-contained plant, or to the supply terminals, if supply is taken from street mains. As the drop is $\frac{1}{2}$ volt on the branches, there should be not more than $1\frac{1}{2}$ or $1\frac{1}{4}$ volt drop over the rest of the wiring. If the run from the fuse boxes to the switchboard does not exceed 20 yd., and if we allow $\frac{3}{4}$ volt drop—that is, at the rate of 1 volt for 25 yd. run—the density will be 800, and for 18 amperes, Table II shows that the sub-mains must be 7/16 size. Suppose the run from switchboard to dynamo is 12 yd.: the total current is 108 amperes, and the drop must not exceed (say) $\frac{1}{2}$ volt, or at the rate of 1 volt per 24 yd. run. This is again a density of 800, and in Table II the nearest size of mains for 108 amperes is 37/16, which would be the size to adopt. The drop over the whole installation would then be well within 2 volts with all lamps on.

The well-known **Woodhouse & Rawson Wiring Tables** are given in the accompanying plate by permission of Mr. Reginald Wallis-Jones. They are self-explanatory, but it may be mentioned that they give the number of yards of single length of cable (not yards of run) for a drop of 2 volts when carrying currents ranging from $\frac{1}{2}$ ampere to 420 amperes. The numbers printed in large type are the number of yards of single length of different conductors for a drop of 2 volts when the density is as nearly as possible 1000 amperes per square inch. When the number of yards is less than 80 the density is over 1000, and when more than 80 the density is less than 1000. It will be seen that 80 yd. of single length of cable for 2 volts drop corresponds to 40 yd. run (double cable) for 2 volts drop, which is the same as 20 yd. run for 1 volt drop, as given above for a density of 1000. The numbers of 60-watt lamps for different currents are given as for 16-candle-power lamps at 100 volts, and these numbers should be multiplied by 2 for 200-volt 16-candle-power lamps, and multiplied by 4 for 200-volt 8-candle-power lamps.

CHAPTER III

WIRING

The lamps or points to be wired should be arranged in convenient **groups or branch circuits** of (say) six 16-candle-power, or ten 8-candle-power lamps, each group being wired to one fuse way and a fuse box. The lights in each room should as far as practicable be on two distinct branch circuits, so that in the event of the fuses on one circuit going, the room is not left in darkness.

In No. 1, Plate XXXVIII, a **four-way fuse board** is shown and one branch circuit from it to four points, representing together six lamps. The fuse board consists of an enamelled slate base in two halves, separated by a hardwood bridge or division plate $\frac{1}{4}$ in. thick. The object of the bridge is to prevent an arc forming across the poles when a pair of fuses blow. On each half plate is mounted a brass or copper bar, carrying fuse terminals or clips for taking fuse-holders, and a terminal on each bar for connecting

PLATE XXXVIIA

RULES APPLYING TO THE TABLES

The figures printed in larger type are under the approximately largest Currents which can be carried by the respective Cables in each row, with a limit of Current density of 1000 amperes per square inch.

the sub-mains. For circuits of 200 volts and over there should be a clear break for these 5-ampere branch fuses of not less than 2 in. The whole is enclosed in a polished wood box with hinged front. The box should be lined inside with stiff asbestos sheet, and in damp situations should be of iron or gunmetal, with watertight glands for the wires, and with the lid clamping down on a rubber gasket.

In the illustration the manner of running the wires to the lamps and switches is shown.

The supply wires are in black and red, as it is usual and convenient for distinguishing the polarity of the wires to have the outside braiding in these colours. There is a third wire (coloured red) which connects the

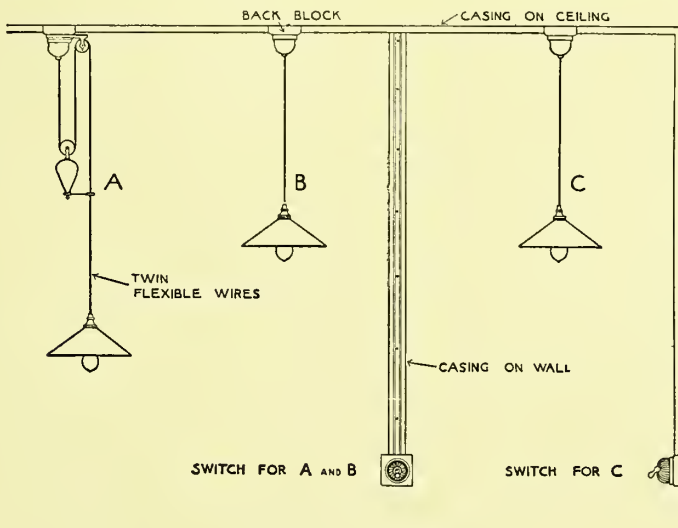


Fig. 761.—Branch Wiring

lamps to the switches; this is known as the *switch wire*. Strictly speaking, the polarity of this wire changes according to whether the lamps are "on" or "off", but when the lamps are on, it has the same polarity as the supply wire connected to the switch, and therefore, like it, is made red in colour.

All joints are avoided by *looping in*, or taking the wires in and out again to the respective fittings as shown. The black live wire is looped in to all lamp points, the red live wire to all switch points, and the switch wires connect together the other poles of the lamps and switches. The 3-light electrolier wiring is arranged with two switches, so that one, two, or three lights may be turned on as required. The illustration shows the number of wires running together in each length of casing or conduit. To the wall-bracket point four wires run down to the light, and three from the light to the switch. Three wires run to the ceiling-pendant point, and also to the switch controlling it. Four wires run to the 3-light electrolier, and also four to the two switches controlling these lights.

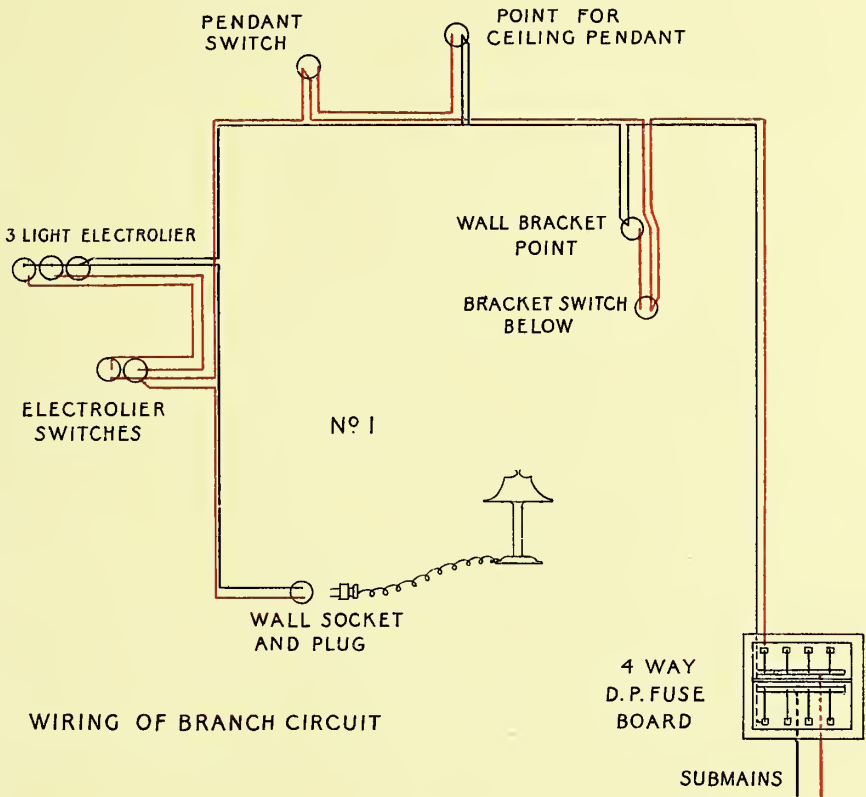
A further illustration of branch wiring is given in fig. 761. One counter-

weight pendant, A, and two fixed single-light pendants, B and C, are on the branch. Two switches are provided, one controlling the lights A and B, and the other the light C. The lamps are suspended by twin flexible wires, each separately insulated and braided, known as *flexible cord*, or simply *cord* or *flex*. With 16-candle-power lamps the flex for the fixed pendants is composed of 35 wires, each No. 40 in size, or as it is generally written, "35/40 flex". The counterweight pendant should have a 70/40 flex on account of the greater weight to be carried. The ceiling roses are of porcelain, containing terminals for connecting the branch wires with the flex. The roses are screwed to polished wood base blocks, the blocks being securely screwed to the joists, or to the laths when the fitting is of light weight.

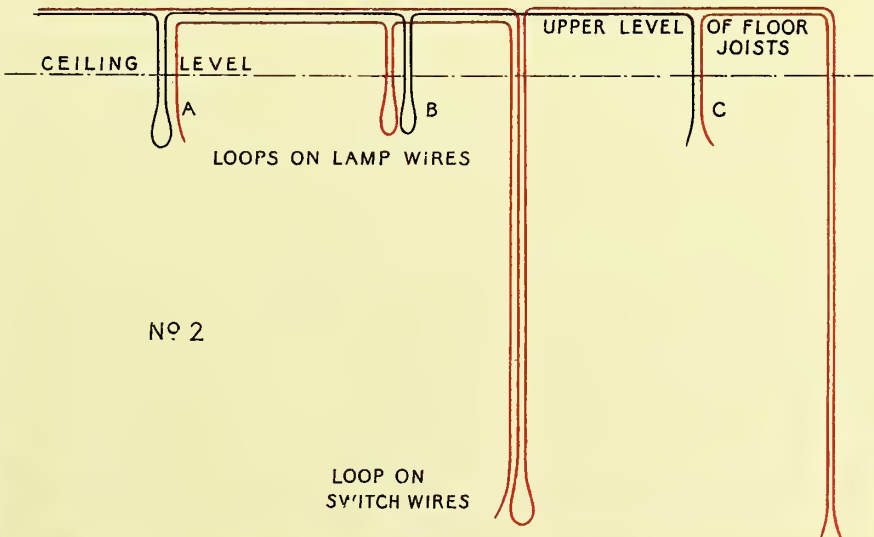
In wiring these lamps the wires are looped in to the lamps and switches as shown in the diagrams, No. 2, Plate XXXVIII, and No. 1, Plate XXXIX. In No. 2, Plate XXXVIII, the actual loops on the wires are seen. The supply wires enter on the left, and the black wire is taken to all three lamps, being looped in on the way to the first two. In like manner the red supply wire is taken to both switches, being looped in to the first switch on the way. The switch wires are also looped in where there is more than one lighting point to a switch. Taking the switch for the lamps A and B, a red wire is run to the first lamp A, then looped in to B, and continued down to the switch. In the case of the other switch wire for the lamp C, no looping is required, as the wire has to connect one lamp only to the switch. The wires are shown as they are actually run in casing or tube, let in flush with the top of the floor joists. The ends and loops for the lamps are taken down in tube close to the side of a joist, when the ceiling-rose block is to be screwed to the joist. The wires then come straight down through the back block.

No 1, Plate XXXIX, shows the actual **connections of the wires to the ceiling roses and switches**. The wires are bared at the top, the copper conductor of each is then doubled on itself, and the end so formed clamped in the terminal of the ceiling rose. For instance, considering the loops (black and red) at B, the end on each is formed in the manner described, and connected each to one of the terminals on the rose. Ceiling roses are specially made with terminals and base holes of large bore for taking the double wires.

Wires in Separate Lengths.—Instead of a continuous length of wire looped in as described, the wiring in long runs may be in separate lengths. In that case the ends are twisted together, and should be soldered where possible. It is, however, impracticable in some cases, such as in short lengths hanging from a ceiling, to solder the ends, and a good job may be made in tinned conductors by opening out the strands, cleaning them carefully, interlacing the strands of the two ends, and twisting them up together with the pliers. In the event of the wires oxidizing and making bad contact with each other, the ends are still both in contact under the same terminal, and the worst that could happen would be that the pair of terminals to one lamp would, in addition to the current for its own lamp, be carrying the current required for all lamps connected after it on the



WIRING OF BRANCH CIRCUIT



No 2

WIRING OF BRANCH CIRCUITS

Negative Wires, black; Positive and Switch Wires, red

same branch, and as the terminals of a good ceiling rose are capable of carrying 5 amperes, and the number of lamps looped together should not by accepted rules exceed 3 amperes, it follows that under these conditions no undue heating can occur when a dry joint is made in this way.

Supposing this were done in the above example (No. 2, Plate XXXVIII) there would be three loose ends at A, four at B, and three at the centre switch. When the ends are brought through, the proper pairs are twisted together temporarily. This is a very necessary precaution if the wires are not in distinguishing colours. If, for instance, all wires were black, there would be four ends of one colour at B, and unless the proper pairs had been twisted together as soon as brought through, it would be impossible to tell the right pairs without retracing them, and the mistake might be made of joining the wires the wrong way. A mistake of this kind is sometimes not discovered until the final test, and time is then taken up in finding out the "short", removing the fitting, and altering the connection. On large jobs with a considerable number of wires, if distinguishing colours are not used, there will be great liability to mistake. In small jobs of only a few lights, and where there are no long runs, it does not so much matter, as there are not many wires, and they can be kept well in sight as the work progresses.

When the supply system has one side earthed, it is important to connect all switches on the insulated or live side of the system. If the single-pole switches used in a building were connected on the earthed conductor, there would still be one side of the wiring and fittings live even with all the switches off. For instance, when switching out all lamps in a room, one side of the wiring would still be live, that is, at an electric pressure or potential above earth, and should there be an accidental contact between this side of the system and a lampholder or fitting, anyone touching this with the hand, and touching anything in connection with earth with any other part of the body, would receive a shock equal to the full voltage of the supply.

When the supply system is three-wire, the neutral or middle wire is earthed, and the two outers are at positive and negative potential respectively. If the installation is large, the three wires are brought into the building, but separated into two distinct circuits, controlled by independent distribution boards. These should be 6 ft. apart, or constructed so that the cover or door to one board only can be opened at one time. From each distribution board the wiring is run exactly as on an ordinary two-wire supply. In this case it is most convenient to have all switch wires one colour (say red), and if this is done no mistake can be made, as the live wire will be one colour on all the wiring from both switchboards. It will nevertheless be the case that red on the wiring from one switchboard will be positive, and from the other board negative. This example shows that it is impossible to carry out all wiring on the rule that wires of one polarity shall always be of one colour.

The interiors of two kinds of **ceiling roses** are illustrated in fig. 762. The branch wires feeding into the roses are shown coming into their respective terminals in pairs, as would be the case when looping in, as

before described. In each rose the usual porcelain bridge separating the terminals at opposite potentials is provided with holes, through which the flexible is threaded to support the weight of the fitting by the flexible itself, and not by the connections at the terminals. In old work, ceiling roses may be found having no such provision, the whole weight of the

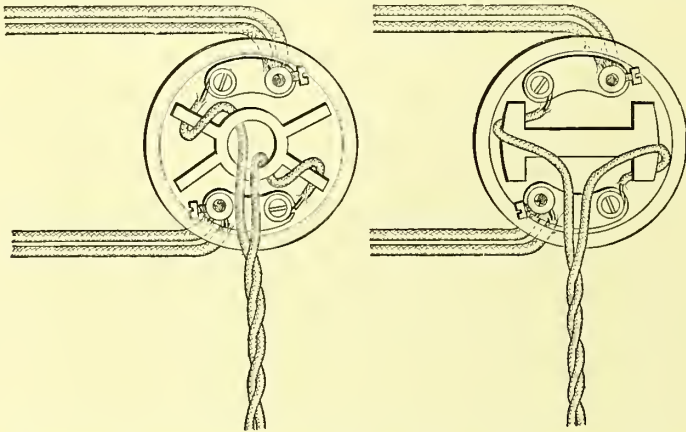


Fig. 762.—Ceiling Roses showing Looping-in of Branch Wires and Attachment of Flexibles

fitting being supported by the terminal contacts, or by a knot in the flex—a very objectionable practice. When a knot is tied in the flex, the weight of the fitting is carried by the cover of the ceiling rose, and this is very likely to give way, as it is only held by a few threads of porcelain. For the same reason it is preferable that the brass ring carrying the top pulley of a counterweight pendant should be clamped between the wood block and the rose base, not between the rose base and the cover.

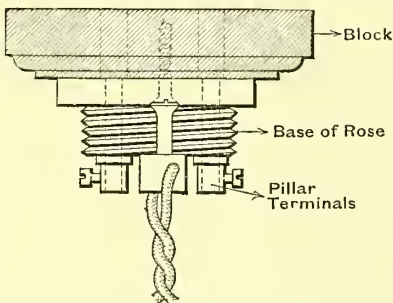


Fig. 763.—Side Elevation of Ceiling Rose

The illustration shows the flex threaded through on each side, so that the weight is properly taken at the bridge. The terminals for the branch wires are of a convenient form, known as *pillar terminals*, cylindrical in shape, with the tightening screw at the side, as shown in fig. 763. The holes through the terminals are continued in a straight line through the base of the rose, so that the ends of the wires can be pushed

down direct into the terminal through the bases.

The terminals for the flex are of a different kind, namely, cheese-headed brass screws with washers. The ends of the flex should be carefully twisted up to resemble a solid wire, with no stray ends sticking out, and then put under the washer and screwed up. The little hook usually made on the end of the wire, before placing it under the terminal, should be made in the same direction as the screw turns when tightening up, as shown in

the illustration. This tends to keep the wire in place should the washer turn with the screw, as it sometimes does.

A **back block or patera** in section is shown screwed to the joist in fig. 764, two screws being used. The wires are threaded through holes in the block before screwing up, and the recess in the front allows for bending the wires around in the manner shown, so as to bring them opposite their respective holes, or for holding a little slack. In this illustration the wires are the same as previously shown at A in No. 2, Plate XXXVIII, and No. 1, Plate XXXIX, two of the wires being looped together. In making the ends the outside braiding is cut back, leaving about $\frac{1}{2}$ in. of the rubber covering exposed, and about $\frac{3}{4}$ in. of bare conductor. The reason for cutting the braiding back farther than the rubber is that the braiding material is a non-insulator, and if it touches the bare copper or the terminal to which the conductor is clamped, there will be surface leakage, and the insulation of the circuit will be lowered. There should be a clear half-inch of rubber insulation between the conductor and the end of the braiding. The ceiling-rose base is then screwed to the block after threading the ends of wires through it. When these screws are entered there will be in all three pairs of holes in the block, and it is of importance to see that they are a fair distance from each other. A good workman will first lay the base on the block and mark out the holes for taking the wires and those for screwing the base to the block, and then make the holes for fixing to the ceiling in a different position, so as to be clear of the others. If this precaution is overlooked, it may happen that when screwing the rose base to the block one or both

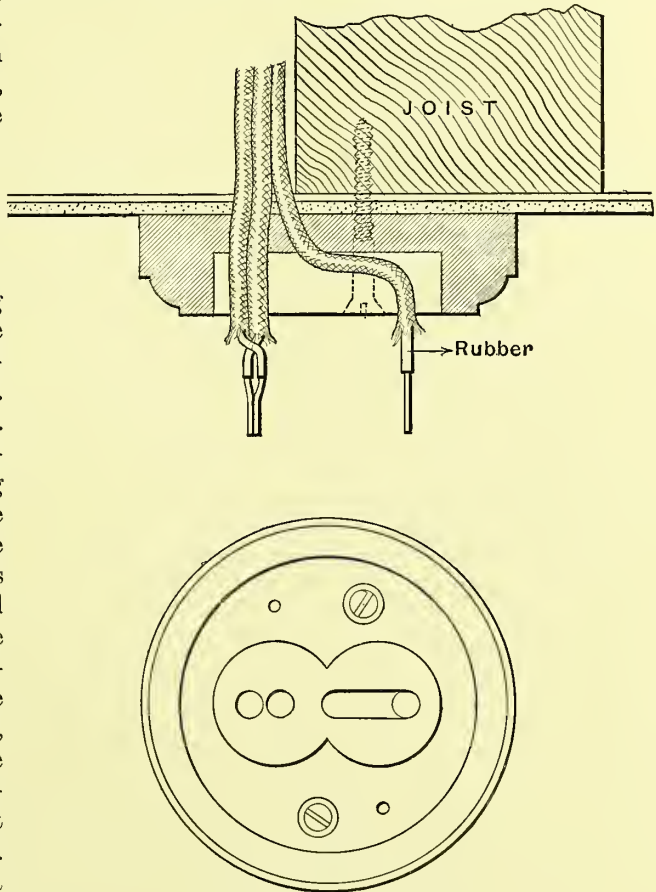


Fig. 764.—Patera for Ceiling Rose

of the screws come foul on the heads of the screws fastening the block to the ceiling. In this case a careless man will leave the base supported by one screw only, or put the base out of centre.

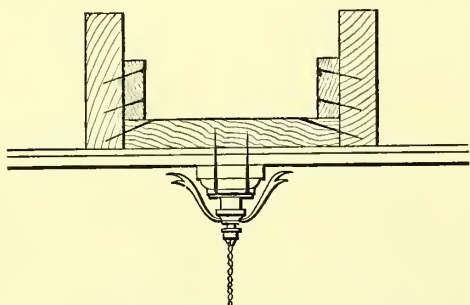


Fig. 765.—Fixing for Electrolier between Joists

batten should be fixed between the joists, as in fig. 765, and the back block screwed up to this. The batten is kept down by two pieces of wood above it, nailed to the joists, so that when screwing up the block to the batten the latter cannot shift.

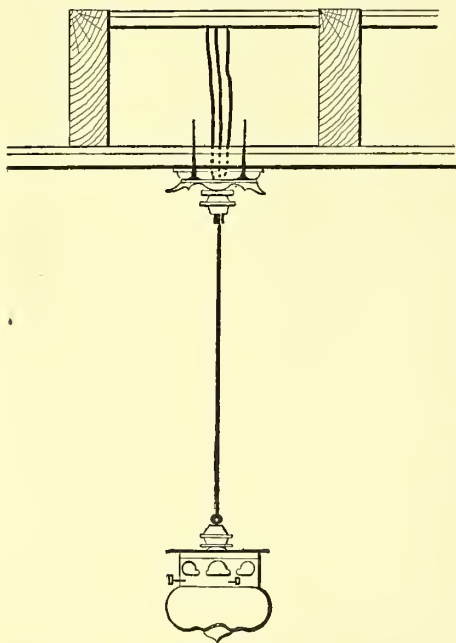


Fig. 766.—Fixing for Single-light Pendant to Plaster Ceiling

For single-light drop pendants the block may be screwed to the laths with lath screws, taking care that they properly enter the laths, and are not holding merely by the edge of the lath or by the plaster only. For heavier suspended fittings, such as electroliers up to five lights, the suspension hook can be safely carried by three long screws into the joist. If the position of the fitting comes between two joists, a piece of 3 in. by 2 in.

An illustration of fixing a **single-light pendant block** to the laths is given in fig. 766, and shows how the short length of wiring from the casing to the block is frequently run. Instead of being completely covered in in casing or tube, as it should be, it is left open and in contact with the plaster where it passes through the ceiling.

The dry or unsoldered joints usually made between branch wires and flex or fitting wires cannot be considered satisfactory. They are taped over and forced back into the recess in the block. The soldering of these joints has the disadvantage of rendering the flexible conductor brittle, and there is the further difficulty in making satisfactory soldered joints owing to the more or less inaccessible positions of the ends. No doubt by more labour and care such joints

could be made satisfactory; for instance, the solder could be applied to the bent end only, leaving the flex untouched where it first comes into contact with the conductor. But a joint between a solid wire and a flex is at the best unsatisfactory.

The best method is to use some sort of **connection box** having terminal

plates, as in a ceiling rose, to which the respective ends could be clamped. Such a connection box, if exposed, might be unsightly—outside a wall bracket, for instance,—and until recently nothing of the kind had been devised which could be concealed behind such a fitting. A design has lately been brought out by the General Electric Company which answers these requirements, and is illustrated in fig. 767. In the centre of the block is a recess, in which is sunk a porcelain base containing three double terminal plates separated by porcelain bridges. The branch wires come in through the holes in the centre, and are connected to their respective terminals. The ends of the fitting wires are also clamped to the same plates, thus making satisfactory connections. Three contact plates are provided, so that two switch wires can be brought in if required. By the use of this simple device, dry joints are entirely avoided, and there is the additional advantage that the fittings can be removed and replaced by others without the cutting of wires or remaking of joints. Brackets, when removed by tenants giving up a house, are frequently pulled away, parting the wires inside, and necessitating the taking down of a panel, or involving some other difficulty to fish the wires back and extend them for the new fittings. Such a fixture as that described obviates all this, besides making a safer job than jointing.

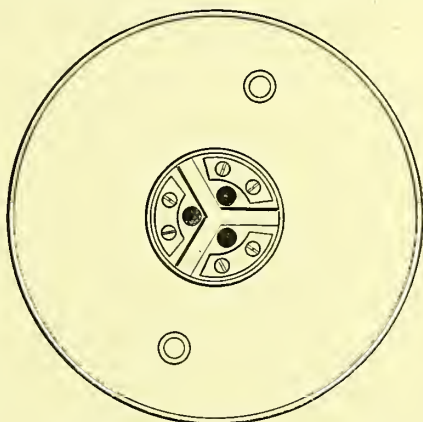


Fig. 767.—Patera with Countersunk Contacts

A detachable connecting device has lately been brought out (Messrs.

J. J. Smith of Holborn Viaduct), by means of which a wall fitting, such as a bracket, can be connected to the circuit by simply fixing it in its place. A socket shown in side and front elevation at A and B (fig. 768) is

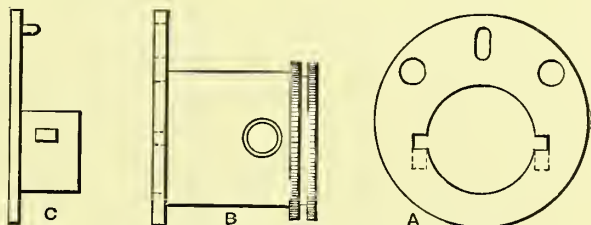


Fig. 768.—Detachable Connector for Wall Fittings

first wired up and fixed in the wall, with the front plate flush with the surface. The plug part, C, is fitted to the bracket and wired permanently to the lamps. The electrical connection between the plug and socket is made by spring contacts, as in an incandescent-lamp socket, and the mechanical connection by a bayonet joint. The pins or lugs on the side of the plug enter the horizontal slots in the face of the socket, and then drop into the vertical slots behind, so holding the fitting in position. The joint between the branch and fitting conductors is avoided, and the fitting can be detached at any time, for cleaning or for removing to another position, without having to break any joints.

Ceiling Plates.—The ordinary porcelain ceiling rose does not lend itself for use with ornamental metal fittings. It may be concealed by a more or less ornamental metal cover, the tips being screwed to the patera, but this is never very satisfactory in appearance. A metal plate with cord grip (fig. 769) is a form in use for a pendant fitting, where (say) a 3-light spider ball is surmounted by a large and somewhat heavy shade. This dispenses

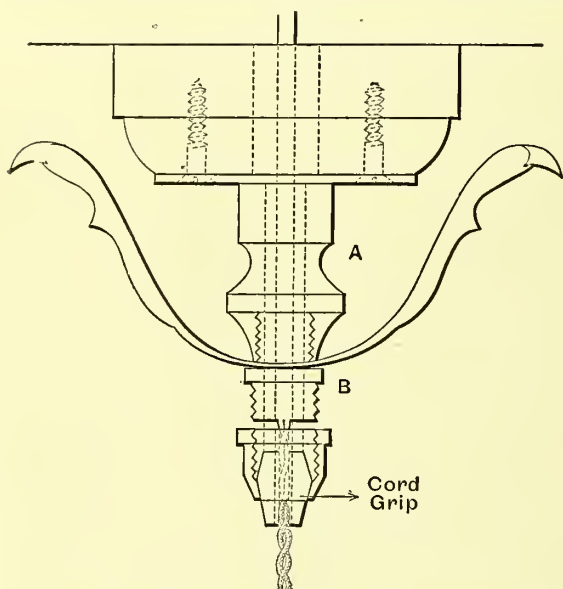


Fig. 769.—Metal Plate, Leaf, and Cord Grip for Ceiling Fitting

altogether with the porcelain ceiling rose, in place of which the brass socket plate A is used. This is screwed to the patera as shown. By means of the nipple B, which screws into the socket of A, a large ornamental metal leaf is secured in position, concealing the plate and patera from view, or sufficiently so to present a finished appearance. The cord-grip socket screws into the lower nipple of B, thus completing the suspension device. The patera of course must itself be secured in a thoroughly safe manner to the joists

direct, as in fig. 764, or between joists, as in fig. 765.

The cord grip is a metal socket, coned at the lower end, and forming a seating for two wood grips. The latter are semicircular in section, and hollowed out in the inside to receive the flex. As the socket is screwed up into the nipple, it rides on to a wider part of the coned grips, thus gripping the flex. The grips have a short and a long coned end, and should be put in with the long end next the exposed part of the flex. The fitter should

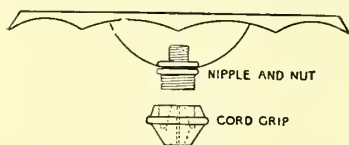
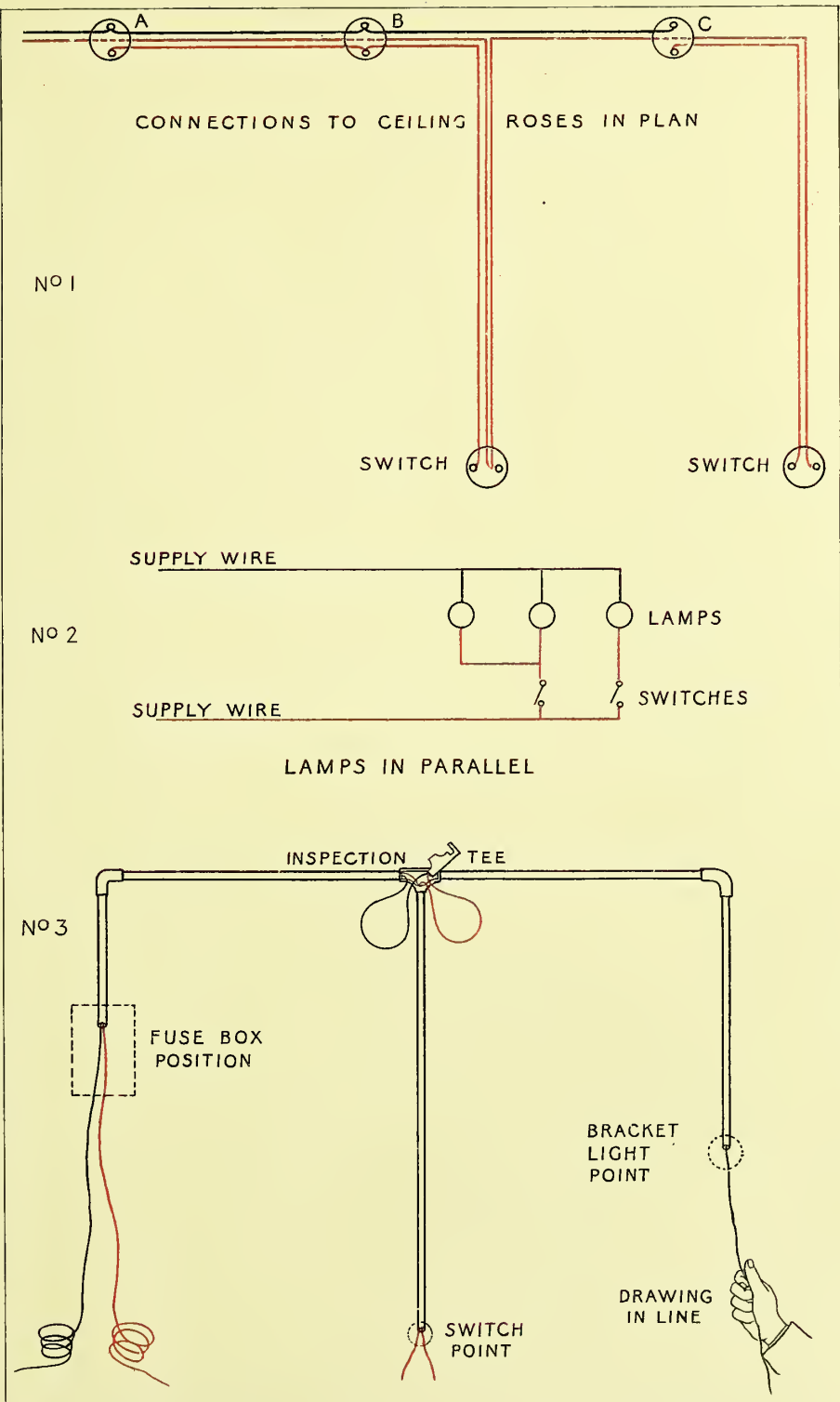


Fig. 770.—Metal Ceiling Rose and Cord Grip

never neglect to notice whether the grips touch each other when screwed up. If they touch, they are probably not gripping at all or imperfectly, and a fresh adjustment should be made. When holding well, the two grips will be slightly apart when screwed up. A trial should always be made

of the tightness of the grip by holding the fitting in one hand and pulling the flex with the other, when if it does not shift it may be relied upon to take the weight.

In this kind of fitting, again, no ceiling rose being provided, dry joints are resorted to. Worse still, the recess in the block is frequently at the back, and the joints squeezed in together, where they are not only quite inaccessible, but have very short ends for any subsequent renewals or



ELECTRIC-LIGHT WIRING
 No. 1.—Branch-circuits; No. 2.—Lamps in Parallel;
 No. 3.—Wires in Tubing

replacements. In a case of this kind, the brass plate A (fig. 769) should be made in the form of a circular box containing three contact plates on a porcelain base, so that the connections can be properly made as in a ceiling rose; or a sunk block, as described and illustrated in fig. 767, should be used in place of the ordinary block.

A simpler kind of metal ceiling rose with cord grip is shown in fig. 770.

Parallel and Series.—Lamps are usually connected in parallel as in the diagram, No. 2, Plate XXXIX. Supposing, for instance, the black supply wire to be positive, current will flow through the lamps from black to red when the switches are closed. The current flows independently through each lamp, and lamps connected up in this way in a circuit are said to be *in parallel* or *in multiple*. They must all be of one voltage, corresponding

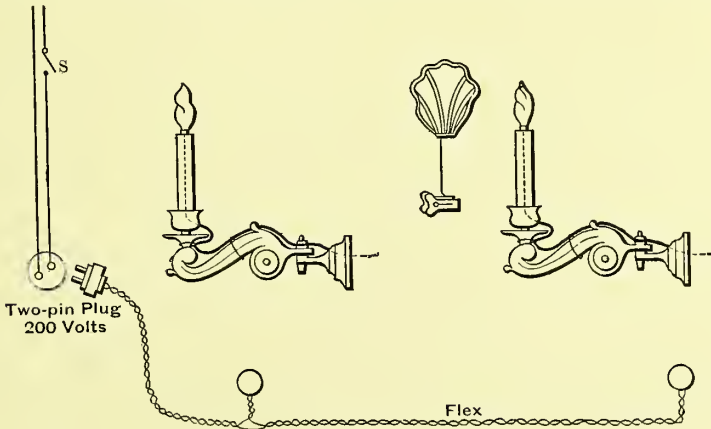


Fig. 771.—Two 100-volt Lamps in Series

to the voltage of the supply. All lamps of the same candle power and voltage take the same current. Lamps of equal voltage but of different candle power take different currents, the current being greater the higher the candle power. As a rule, lamps of 5- and 8-candle power are used for private-house lighting, 16-candle power for large rooms and business premises, and 50- and 100-candle power for halls, shop fronts, and other more spacious situations.

Lamps are said to be connected *in series* when they are connected so that the current flows through one after the other or in succession. It is often required in house lighting to use small lamps of 5- or 8-candle power for candle wall brackets, chandeliers, or piano sconces, and if the supply is at 200 volts, or over, it is better to use lamps of half this voltage (100 to 120 volts) connected in series, because lamps of these small sizes are more durable on the lower voltage. In fig. 771 are shown two 100-volt candle lamps in piano-sconce fittings wired in series on a 200-volt circuit. The branch supply wires come to a two-pin socket, fixed on the wall or skirting board near by, and a single-pole switch is inserted at some convenient point in the branch. The two-pin plug is wired with flex to the

lamps as indicated. By following these wires in the figure, it will be seen that the current passes successively, or in series, through both lamps.

Sometimes a wall bracket contains an odd number of candle fittings

(say five). On a 200-volt supply, if it is desired to control the lights by two switches, the lamps must be of different voltages, say two 100-volt lamps in series and three 66-volt lamps in series. If all the five lamps are controlled by one switch, they can be wired in series, when each lamp will take 40 volts. In

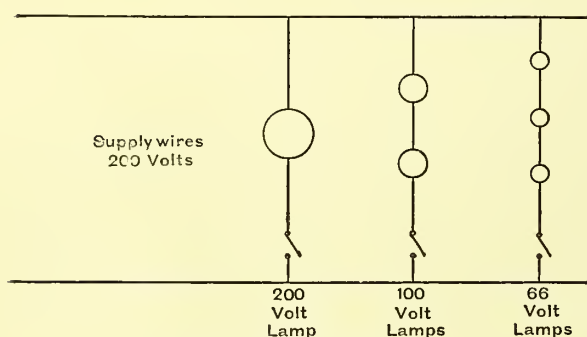


Fig. 772.—Lamps in Multiple Series

the first arrangement—that is, with two switches—there are two or more rows of lamps in parallel or multiple, as in fig. 772, each row containing lamps in series. This arrangement is known as *multiple series*, and in

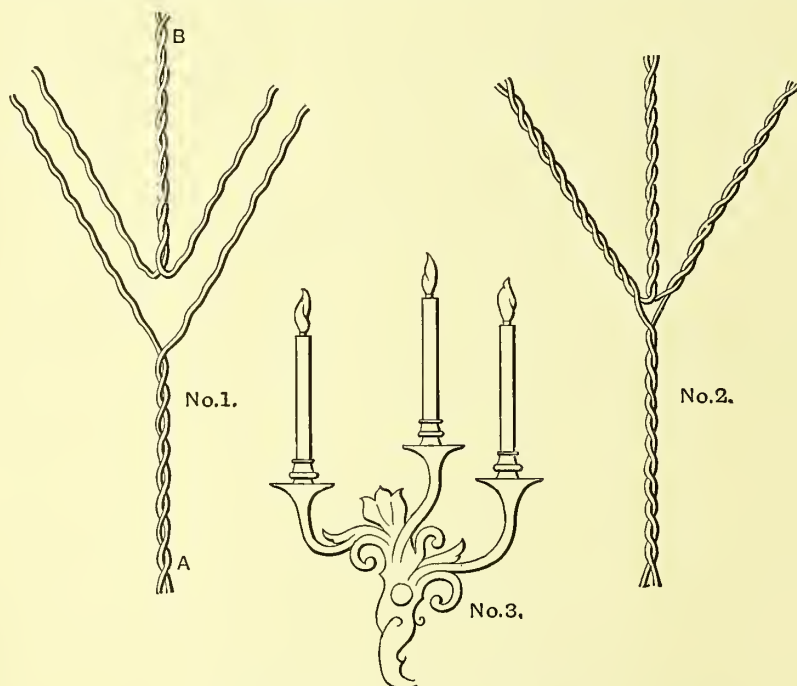


Fig. 773.—Wiring for Three-candle Bracket

incandescent lighting is only used in special cases such as the above. In arc lighting it is greatly in use.

In a three-light candle bracket (No. 3, fig. 773) three 66-volt lamps

would be fitted on a 200-volt circuit, and the flex made up as shown. The part A, No. 1, coming up from the joint with the branch wires, is divided out into two single parts long enough to reach the two outside lamps. Another piece of flexible, B, is taken and divided into two similar single parts, as shown. The single parts of each piece are then twisted together, as shown in No. 2, forming a pair of wires for each of the three lamps, and when wired up in this way, current will pass through the lamps in succession or in series.

Plug Sockets.—The porcelain or china base of a two-pin wall socket is shown in fig. 774. The contact plates are provided with pillar terminals for the wires, and tapped holes to receive the socket screws. One of these is shown at A, and consists of a brass tube or socket, screwed on the outside, and with a saw cut at the top for screwing in. There is a shoulder at the top, so that the two screws secure the cover to the base, and also serve the purpose of sockets. The two-pin plug (fig. 775) used in connection with the socket

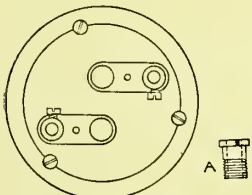


Fig. 774.—China Base of Two-pin Wall Socket

is in the latest patterns provided with a porcelain bridge, through which the wires of the flexible are threaded, thus taking the strain off the terminals in the same way as described for ceiling roses.

Branch Fuses.—It is against rules to have fuses

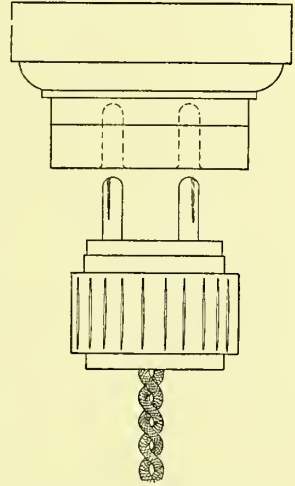


Fig. 775.—Two-pin Socket and Plug

in sockets or ceiling roses, and they must never be fixed in them. Modern sockets and roses have no fuse terminals, but these will be found in old patterns in many existing installations. The reason for the prohibition is that in ceiling roses and wall sockets both poles of the circuit are brought close together, and a fuse blowing on one pole will generally start an arc across both poles. When there is the full voltage between two wires or two base plates, as near together as they are in these small pieces of apparatus, the greatest care must be taken to prevent a short circuit taking place. The best practice for branch fuses is to place these all together in fuse boxes, where parts between which there is the full voltage of the circuit are kept at a proper distance and shielded from each other. When centralized in this manner, fuses are easily accessible for replacement.

CHAPTER IV

WOOD CASING

For enclosing electric-light wires the well-known **double-groove wood casing** closed with fluted capping is most generally used on walls and ceilings, where it is necessary that there should be as little disturbance as possible to existing surfaces. Although in some respects simple to run, and of excellent appearance when properly put up, any want of care in fixing the casing or in mitring or butting the joints in the capping gives a character of unsightliness and cheapness to the whole of the work. Where the ceiling is panelled the casing can generally be arranged to harmonize with the scheme, and in such instances it should be carried right across the ceiling in dummy, instead of stopping at the lighting point. Brick walls should be carefully plugged and the casing screwed through the centre fillet to the plugs. On lath-and-plaster partitions and ceilings casing should be screwed to the laths by lath screws. In buildings of reinforced concrete, holes must be drilled and wood plugs cemented in for the purpose of screwing up the casing. Fig. 776 illustrates the ordinary form of casing and capping made in American whitewood, a wood free from knots and of uniform grain. Before use it should be painted all over in two coats of good priming, and allowed to get thoroughly dry.

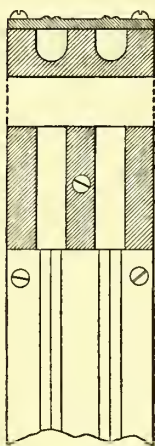


Fig. 776.—Wood Casing and Capping

For electric-light wiring in occupied houses it is frequently stipulated that there shall be as little cutting away or disturbance of the decorations as possible, and all work must then be on the surface. Under these circumstances casing is more suitable than piping from the point of view of appearance and can be made to look very well when properly run and painted to harmonize with the surroundings.

Sunk Casings.—It used to be the practice, for the sake of appearance in the best work, to sink casing flush with the surface of the plaster, and many old installations are to be found where the casing is run this way. From an electrical point of view this is not satisfactory, as a certain amount of moisture is always absorbed by the wood, and the insulation of the whole job becomes lowered by surface leakage. The Institution Rules prohibit casing being totally sunk beneath plaster, and may also be taken to mean that any sinking at all is discountenanced. Enamelled steel solid tubing is the best to use in all sunk work. This preserves the wiring from moisture, and is able to withstand a nail which may be driven against it.

In large premises the mains and sub-mains are best run in **smooth-bore screwed iron or steel barrel**. If the pressure exceeds 250 volts, as in the case of a building being wired on the three-wire system at (say) 200 volts with 400 volts on the outers, the whole of the wiring must be in iron piping, and the piping must be in continuous metallic connection throughout and

in good contact with earth. In any supply system having one pole earthed all installations, where the wiring is in iron pipe, should have the pipes bonded well together and well earthed. This precaution is necessary for prevention of shock to persons touching the pipework, which may at any time become live through failure of the insulation of one of the wires inside.

In fig. 777 is shown a run of casing between a ceiling pendant and a wall switch for rooms having plaster cornices and wood floors. The plaster and a little of the brickwork are cut away at the back of the cornice, by means of long bent chisels or jumpers. This is done by working from above and below, removing only what is necessary to give the required clearance, and taking care to keep the chase narrow, so that the casing when in position will conceal it. It is sometimes possible to push up into the chase a short piece of casing in two or three lengths (of course narrower than the surface casing so as to be covered by it), the surface casing being screwed to the piece at the back at A. A piece of "lead-compo" pipe or flexible steel pipe, as in the illustration, makes an equally good job. Flexible steel tubing, oval in section, is now used largely for runs behind cornices and skirting boards.

Above the ceiling the casing is run in recesses checked out of the top of the joists, that is, if the run is across the joists. A floor board is lifted and the joists checked out exactly to the depth and width of the casing and capping. The floor board is refixed by screws so as to be again accessible at any time. If the run is parallel to the joists, traps or sections of floor board between the pair of joists containing the run have to be cut at intervals for passing in the casing. In the illustration the wiring is finished from casing to ceiling block by a short length of compo or flexible steel pipe. This protects the wires completely from the plaster. The same method is adopted when it is necessary to run the wiring through the ceiling to the wall in the room above. Care must be taken to trim the ends of the pipe smooth, so that the wires may not be damaged afterwards. Fig. 778 shows the finishing of casing when wires are taken in pipe behind a cornice.

For finishing the casing neatly to the switch block, the under side of the block is checked out to fit exactly over the casing. This is shown for a

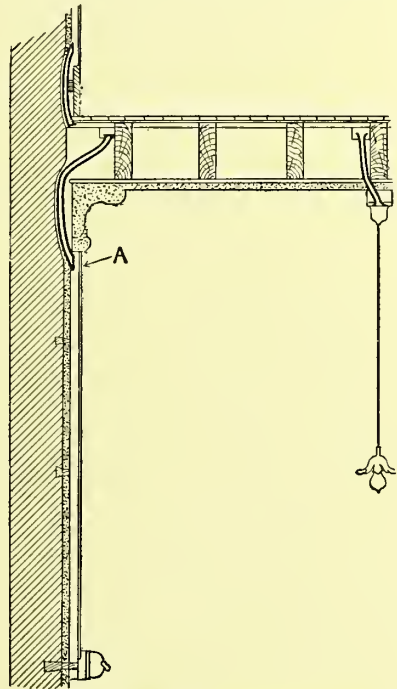


Fig. 777.—Casing to Pendant and Switch

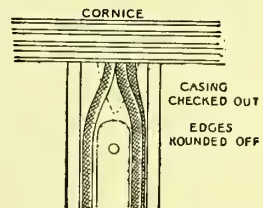


Fig. 778.—Casing Checked Out to receive Wires from Tubing behind Cornice

socket block in fig. 779, the lower view of which shows the back of the block checked out and the position of wire holes and screw holes. The block then fits over the casing, and the capping is taken just within the block recess. In this way a neat finish is secured without scribing the capping and cutting it to fit the block.

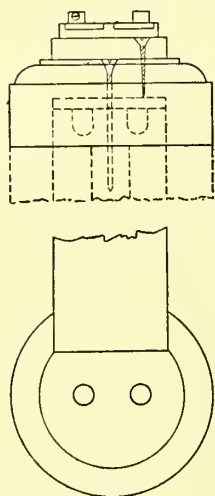


Fig. 779.—Block Checked Out for Casing

Screws.—For screwing up capping $\frac{1}{2}$ -in. No. 4 screws are used for casing up to $1\frac{1}{2}$ in. in width, $\frac{5}{8}$ -in. No. 5 up to $2\frac{1}{2}$ -in. casing, $\frac{3}{4}$ -in. No. 6 up to $3\frac{1}{2}$ -in., and $\frac{7}{8}$ -in. No. 7 up to $4\frac{1}{2}$ -in. The screws should be spaced at equal distances, except at the joints in capping, where the screws should be put close to the joint on either side. In all casing over 2 in. wide the capping screws should be on the outside fillets.

Intersections.—It is frequently necessary to cross casing at right angles. This is done by bridging one run over the other as in fig. 780. One run of casing is laid first complete with wires but without capping, as shown at A A in No. 1. The other run, B B, is laid up close to the first without wires or capping, as shown in No. 2. A piece of casing is then cut to a length of 12 in. or 15 in. to form the bridge. This piece, shown

at C C in the figure, is chamfered off at the ends 4 in. to 6 in. in the length of the casing, as shown at E F, E F, in No. 2, and the grooves are cut out from the ends up to nearly the point where the chamfer begins. This

cutting away of the grooves or forking is shown at D D in No. 1, and it is done so that wires passing from the surface casing B, up and down the inclines of the bridge piece, may be at the same depth in the casing all the way. If not forked, of course, the wire on the incline would lie in the place where the capping ought to go. The bridge piece is screwed to the casing immediately under it, and the wires are then run in the casing B B continuously and across

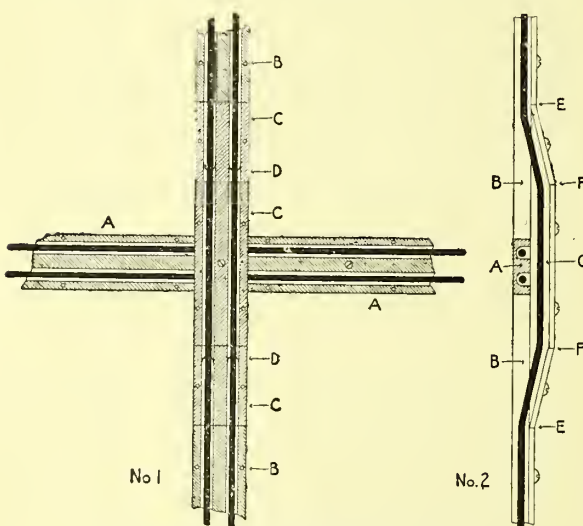


Fig. 780.—Right-angled Crossing in Wood Casing

the bridge as shown. This keeps the two runs quite distinct, and the wires at opposite potentials are kept apart. The same method is useful when a run of casing has to cross or jump over an obstruction, such as a

run of pipes or the like. In a case like this the bottom casing BB is stopped off on each side of the obstruction, and the bridge carried over in the same way. When the wires have been laid the capping is screwed on. The capping shown covering the casing BB, and also the bridge piece, are usually in one piece. This is done by making saw cuts half through the capping on the underside at FF and on the outside at EE, when the capping can be bent to follow the inclines, thus avoiding any joint and presenting a neat appearance.

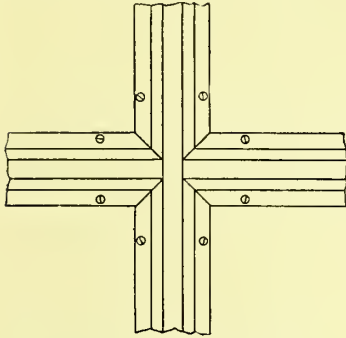


Fig. 781.—Mitred Crossing in Wood Casing

Sometimes, for the sake of appearance, dummy half-bridge pieces are fitted upon the casing AA on each side, so leading the capping from all four parts up to the centre of the crossing, where the pieces are neatly mitred together as in fig. 781.

Tee bridges are made in the same way where necessary—that is, a full bridge is fitted to the main run joining on to a half bridge on the tee branch. The run-through wiring is laid in the main casing beneath the bridge, and the looping-in wires to be run from the main to the branch, and out again to the main casing, are laid in the grooves of the bridge pieces, and thus are separated from the main wires where they cross. By this method the crossing part of the casing protrudes from the surface more than the ordinary runs, and where this is considered objectionable the crossing or tee is made by a short piece of sunk casing, so keeping the whole casing at one distance from the wall or ceiling. This device, however, is rarely now considered necessary.

CHAPTER V

METAL TUBING

When wires are run in pipes certain precautions are necessary which do not apply to casing work. It may at some future time be necessary to withdraw some of the wires either for repairs or alterations, and this is impossible if there are too many bends in the pipes, or if the bends are too sharp. The bore of the pipes should be smooth, and free from rags, fins, or burrs, as the insulating covering on the wires is easily damaged. If the insulation is damaged it may not show itself at the time, but trouble is certain to develop later. Another point to bear in mind is that there is always a tendency for water to collect in the pipes unless means are taken to prevent it. Whenever sweating occurs on walls or ceilings on which pipes are fixed, it is quite probable that sweating will occur inside the pipes as well. It is practically impossible to make an electric-pipe system so tight that air will not get in. It must be assumed, therefore,

that internal condensation will occur, and precautions against accumulation of condensed water must be taken. This should be done just in the same way as if we were dealing with gas pipes; the pipe, whenever possible, should be given a "dip", and drain outlets provided at the lowest points. There is less danger of internal condensation if the pipes are stepped off the walls and ceilings, so as to leave an air space all round them.

In a complete piping job the piping should be properly connected, metal to metal, throughout, so that any leakage can be easily detected. If disjointed, a leak may occur in one section without being found out till serious trouble occurs. The piping should be "earthed"—that is, properly connected with some earthed metal, such as a water pipe or the lead sheath of the supply mains. When pipes are not properly earthed, an unpleasant or even dangerous shock may be received by anyone touching the pipe if there happens to be a leak from one of the wires inside. The best methods of earthing will be dealt with later.

Wires can be run in any kind of piping, but for work on circuits exceeding 250 volts pressure, **screwed iron or steel barrel** is essential. This barrel must be electrically continuous throughout, that is, it must be connected, metal to metal, right through. All switches, fuses, and contacts of



Fig. 782.—Simplex Tube and Slip Socket

any kind must be enclosed in iron boxes, and these boxes must be provided with screwed holes to take the pipes, so that not an inch of wire can be seen anywhere. This

is a Home Office and Board of Trade requirement, and applies chiefly to electric-motor work, as electric lights in buildings are not at present run on circuits of over 250 volts. Although not compulsory on circuits of less than 250 volts, screwed iron barrel is frequently used in important lighting installations, as it is generally considered to make the best and safest job.

For the bulk of wiring work, however, this system is too expensive, and a lighter class of piping is used, commonly known as "**simplex**" tubing, because it was first introduced by the Simplex Company. This piping, which is now supplied by several firms, is, like bedstead tubing, a light steel tube with an open seam throughout its length, and is black-japanned inside and out. It is known as "Ordinary" in the trade, or "Close-joint". It is too thin to take a screw thread, and joints are made by *slip sockets*, or short pieces of tube having a smooth bore large enough to slip over the two ends of the pipe to be joined (fig. 782). It is most essential in this system to cut the conduit long enough to enter the slip sockets well home, and an extra length of $\frac{5}{8}$ in. or $\frac{3}{4}$ in. should be allowed over the dead length between points for this purpose. If this precaution is omitted, the tube has not sufficient bearing in the socket, and if any jar or vibration of the surface occurs it will come adrift, thus leaving the whole weight of the tube and wires to be supported by the wires where they pass the broken joint. It will need very little time, if the vibration continues, to damage the insulation at this point. Although this precaution is so simple, it is fre-

quently neglected, and is the cause of a good many faults. Another precaution necessary in this class of conduit wiring is to support the tubes properly at a sufficient number of points to prevent sagging. The inside

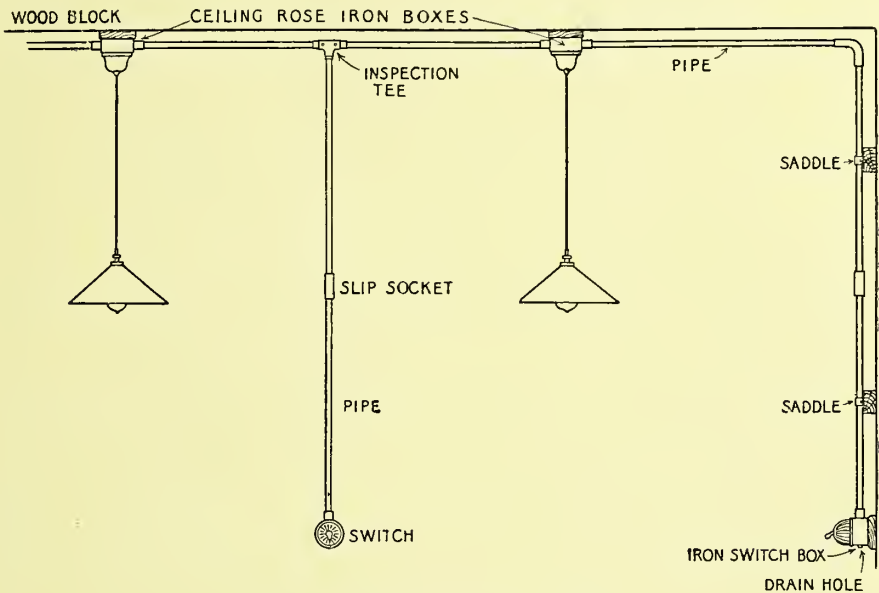


Fig. 783.—Wiring in Tubes for Two Pendants

ends of tubes, after cutting with a hack saw, must always be trimmed with a half-round file or rimer to remove all burrs.

Tees, bends, elbows, and other fittings, such as metal switch boxes and ceiling-rose boxes, are made to suit the pipe, although it is not absolutely necessary to use the metal boxes if not desired, as wood blocks can be used instead. When metal boxes are used, it is advisable to interpose a fibre disc between the porcelain base and the box, to minimize surface leakage.

A piping arrangement of wiring is shown in fig. 783, with the **switch** and **ceiling-rose boxes** mounted on thin wood back blocks. These are advisable, if the walls and ceilings are of masonry, to prevent rusting of the backs. If on wood or lath-and-plaster partitions, these back blocks may be dispensed with. The pipes are shown a little off the wall and ceiling, which they would be naturally if straight, unless the switches and ceiling boxes are sunk a little to bring the sockets flush. As already pointed out, it is an advantage to set the pipes out a little, so as to get a circulation of air round them, and so reduce condensation to a minimum.

If **wood blocks** are used, instead of the metal switch and ceiling-rose boxes, there would be a disconnection of the pipes at each ceiling rose, and

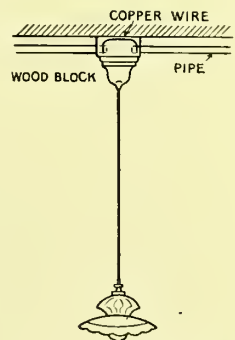


Fig. 784.—Steel Tubes connected with Copper Wire across Wood Block

the pipe ends should, in order to maintain electrical continuity, be joined across by means of a copper wire. This is shown in fig. 784.

Threading-in System.—The system of threading the wires into the pipes, or, in other words, sliding the pipes on to the wires during course of erection, is often done in very cheap work, such, for instance, as when a builder wires a row of houses during erection. In this class of work the cheapest kind of conduit—the open seam—is often used, and the pipes are threaded on to the wires and nailed against the walls, and afterwards completely covered with plaster. Although this system is very largely used, it is not at all to be recommended, except on the score of cheapness. In an installation of this sort it would be a matter of impossibility to withdraw any wire afterwards in case of a failure or fault occurring. In such an event it would in all probability be necessary to cut out the pipes from the plaster, or to run new pipes entirely on the surface and connect them up to the nearest place where the pipes could be got at.

Drawing-in System.—The piping and fittings should be erected before the insulated wire is drawn in, and a drawing-in line should be threaded through the pipe during erection. This line is usually an iron or steel wire of about No. 16 gauge, and a foot or so is left out at each outlet. It is in drawing the wires into the pipes that they are liable to be damaged. It should not be forgotten that electric-light wires are made of soft copper, and also that the insulating material is easily scraped off. If too much strain is put on the wires by attempting to draw them through very long lengths of piping or through numerous bends, the insulation may be cut or torn off the wires, or the wires themselves may be stretched until they break inside the insulation. A break in the wires would most probably not be discovered till the current was put on, when it would be found that certain lamps did not light up. Even if the wires were not strained to the breaking point, stretching, of course, reduces the section of the wires, and so reduces their carrying capacity; the insulation is also seriously damaged by excessive stretching.

Obviously, then, it is very important not to try to pull wires through a line of piping if it is found to require considerable force to do so. Oil or grease must on no account be used on the wires or in the pipes. A little French chalk or powdered soapstone may be used to reduce the stickiness of the insulating covering, but if much force is necessary, either the pipes are too small or there are too many bends.

It is a good plan never to pull wires through more than one bend or elbow. This does not mean that gaps are to be left in the pipes, but that every alternate fitting, whether it be a bend, a tee, or an elbow, should be of the "inspection" type—that is, it should have a removable cover which can be taken off in order to draw the wires through in easy stages. The idea will be clear by a reference to No. 3, Plate XXXIX. The run of the circuit is from a fuse box up to the ceiling, where an ordinary bend is fitted, then along the wall to an inspection tee, whence a pipe is dropped to a switch position, another pipe being continued from the tee along the wall to a bend, where a vertical pipe is dropped to a bracket light. In putting up the piping a fishing wire would be threaded through the pipes from the

fuse box to the switch, and another from the switch to the light. Two wires (a black and a red) are drawn through together by the fishing wire as far as the inspection tee. There they are hooked out, and the black end is disconnected and made fast, while sufficient red wire is first pulled through to reach to the switch, and it is then pulled to the switch point by the fishing wire, about a foot being left out for connecting up. One fishing wire still remains in the switch-wire tube, and to this a fresh end of red wire is twisted. This is then pulled through from the lighting-point end, and when the red wire reaches the inspection tee it is hooked through and the free end of the black wire is joined on, sufficient black and red being pulled through to reach the lighting point, where the two wires are pulled through together to the end. The diagram No. 3, Plate XXXIX, shows the loops of wire left through the inspection tee ready for drawing through to the end.

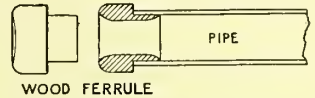


Fig. 785.—Wood Ferrule used in Drawing Wires through Tubes

This little run has been described in detail as an example of how to proceed with branch wiring. It might not be a difficult matter to pull a pair of wires through two bends. It is just a question of how much room there is in the pipes and bends. But it must always be kept in view that alterations may be made after the pipes are erected, necessitating extra wires, and each additional wire in a pipe adds very much to the difficulty of drawing in. It is therefore a wise plan to make every alternate bend or fitting of a type that permits of access to the wires. It is also essential that the pipes should be very securely fixed, as otherwise the strain of pulling the wires through is apt to break the pipe joints.

As a protection to the wires during drawing in, a **wood ferrule** should be fitted in the inlet. These ferrules are standard articles supplied by the makers of the pipes, and are bell-mouthed, as shown in the section fig. 785. The ends of all pipes which do not terminate in boxes or fittings of some kind should be finished with wood ferrules, to prevent the wires being chafed against the sharp edges.

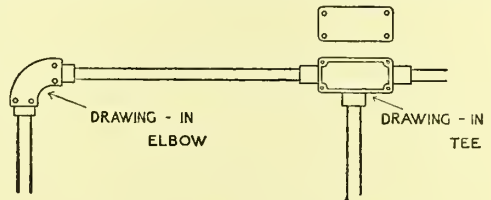


Fig. 786.—Drawing-in Boxes, Elbow and Tee

In dealing with comparatively large conductors, (say) stranded cable of 7/18 and over, the openings in inspection bends and tees, &c., are not large enough to be used for drawing in, so it is advisable to use **drawing-in boxes** (fig. 786). These are larger and more roomy than the inspection fittings.

Although open-seam piping with slip sockets has been very largely used, it is suitable for dry interior work only, and should not be used in skeleton buildings—that is, in buildings which are wired during erection. For work of this nature **solid tubing** is preferable. Ordinary gas barrel is often used, but this is unnecessarily heavy for small wires, and special light steel tubing with a smooth bore, known generally as *steel conduit*, is preferable. This conduit is manufactured in light and heavy gauges and

in several different ways. The Simplex Company make two kinds of solid tube in the light gauge, namely, *brazed* and *seamless*; and three kinds in the heavy gauge, namely, *welded*, *brazed*, and *solid-drawn*. The light-gauge brazed is simply the ordinary open-seam conduit already referred to, with the two edges of the seam brazed together. The light-gauge seamless is a solid-drawn steel tube. The heavy gauges, brazed and solid-drawn, are similarly made, but in heavier metal; welded tube, heavy gauge, is known as *wireduct*. In the lighter qualities the metal is not thick enough to take an ordinary full gas thread, and special dies are used when the joints are screwed.

The British Standard Specification for steel conduits for electrical work, issued by the Engineering Standards Committee, divides steel conduit into two classes:—(A) “plain” and (B) “screwed”. The plain class is the light-gauge slip-socket system already referred to. The screwed class consists of heavy-gauge conduit screwed at both ends with the Whitworth form of thread. The couplers are also screwed inside throughout their entire length with a right-handed Whitworth form of thread of a specified number of threads per inch. Both classes of conduit are obtainable in straight lengths of 10, 12, or 14 ft., and of the respective thicknesses specified. Exactness of diameters of conduit, sockets, and couplers is essential, and standard gauges are specified and deposited with the National Physical Laboratory for purposes of reference. Reference gauges are copies of these for the use of manufacturers to check their own shop gauges. The radii of normal bends vary from $1\frac{7}{8}$ in. to $8\frac{1}{2}$ in. for conduit of $\frac{5}{8}$ in. to 2 in. outside diameter, ensuring a fairly large sweep for drawing the cables through. Sharp bends or elbows are not recognized. The Standard Wire Gauge (S.W.G.) has been adopted instead of the Birmingham Wire Gauge hitherto in use.

When screwed piping is used, the ends of the pipe must be trimmed, after cutting and screwing, to remove the sharp edges; and oil or red lead must be carefully wiped from the interior, as oil is very destructive to rubber, of which the insulation is largely composed.

Screwed joints should be used on all piping buried in cement or plaster, or fixed in damp situations. It is found that steel conduit rusts rapidly when sunk in wet plaster or cement, and for this reason galvanized conduit is preferable. In using the latter it is important that the pipes should be reamed out after galvanizing, to remove any rags or fins, &c.; otherwise there is considerable risk of damage to the insulation.

In chemical and kindred factories, where the cables and tubes are subject to moisture impregnated with acids or alkalies or exposed to weather, it is advisable to use the rather more expensive galvanized conduit and fittings throughout, as otherwise the tubes soon suffer from rust and corrosion.

Armoured Conduit.—For installations in very damp places, or places subjected to very varying temperatures and degrees of moisture, which have a tendency to produce excessive condensation in the pipes, it is better to use what is known as *armorduct*—that is, armoured conduit. This is a steel tube having a composition lining. The composition is of a semi-insu-

lating character, and being a bad conductor of heat, tends to keep a more uniform temperature inside the pipes than would be the case without the lining, and in this way prevents, or very largely reduces, any condensation that would otherwise take place. Armorduct is of course more expensive than ordinary pipe, but for positions subjected to the conditions named above is well worth the extra price. In the colonies this kind of conduit is very largely used, in consequence of the great changes in the temperature and humidity of the air.

Number of Wires in a Pipe.—Although there is no hard-and-fast general rule limiting the number of wires which may be contained in one pipe, it is very desirable that some limit should be made. The rule of the Edinburgh Corporation is that not more than four wires may be run in one pipe, and this is a very good rule, for when this number is exceeded it becomes a very difficult matter, if not impossible, to draw out afterwards any defective wire without pulling out all the others. When the pipes are threaded on the wires as the work proceeds, a larger number of wires can usually be got into a given tube than when the wires are drawn in after erection of the conduit.

TABLE IV.—NUMBERS OF INSULATED WIRES AND CABLES OF VARIOUS SIZES WHICH CAN BE THREADED OR DRAWN INTO STEEL CONDUIT OF THE DIMENSIONS SPECIFIED BY THE ENGINEERING STANDARDS COMMITTEE.

Size of Conductor in S.W.G.	Light-gauge Conduit.								Heavy-gauge Conduit.							
	Drawing-in Sizes,								Drawing-in Sizes,							
	$\frac{5}{8}$ "	$\frac{3}{4}$ "	$\frac{7}{8}$ "	1"	1 $\frac{1}{4}$ "	1 $\frac{1}{2}$ "	2"		$\frac{5}{8}$ "	$\frac{3}{4}$ "	$\frac{7}{8}$ "	1"	1 $\frac{1}{4}$ "	1 $\frac{1}{2}$ "	2"	
	Threading Sizes,								Threading Sizes,							
	$\frac{1}{2}$ "	$\frac{5}{8}$ "	$\frac{3}{4}$ "	$\frac{7}{8}$ "	1"	1 $\frac{1}{4}$ "	1 $\frac{1}{2}$ "	2"	$\frac{1}{2}$ "	$\frac{5}{8}$ "	$\frac{3}{4}$ "	$\frac{7}{8}$ "	1"	1 $\frac{1}{4}$ "	1 $\frac{1}{2}$ "	2"
20	3								2	4						
18	2	4								3	3					
16	2	3	4							2	3	4				
3/22	3	4								3	3					
3/20	2	4								2	3	4				
7/21 $\frac{1}{2}$		2	3	4							2	3				
7/20		2	3	4								2	4			
7/18				3	4							2	3	4		
7/16					2								2			
7/14						2									2	
19/18						2									2	
19/16							2									2
19/14								2								2

Note.—In 7/16 size and over it is advisable not to run more than one pair of wires in one tube.

Table IV gives the number of wires that can be got into tubes of various sizes without crowding, both for threading and drawing in. In drawing in it is assumed that every alternate bend or fitting is an inspection fitting. The sizes of the conductors only are given, but it is understood that the conductors are insulated with vulcanized rubber and taped and braided to

ordinary thicknesses. Makers' standards differ somewhat for outside diameters of insulated wires, but not to an extent that would modify the sizes of tube given in the table. The sizes of conductors chiefly in use are given, and no more than four wires in any single tube are included in the table, as it is not good practice to exceed this number. The gauges of conduit are according to the Engineering Standards Committee's Specification. The

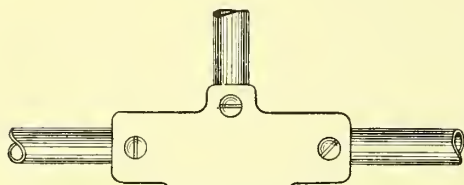
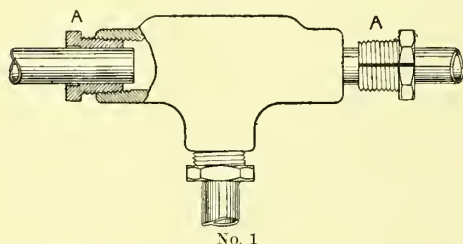


Fig. 787.—Tee fixed to Pipes with Set Screws

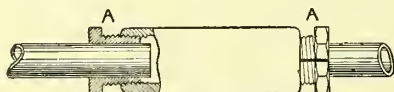
sizes given in inches are the outside diameters of the tubes.

As already mentioned, the **cost of screwed piping** has retarded its general adoption. Considerable time and labour are absorbed in screwing the pipes, and several devices have been introduced with a view to cheapening the cost of erection by doing away with screwing but without sacrificing any of the advantages of the screwed system. These devices take the form of set screws, screwed nipples, or grip-nuts.

The simplest arrangement is that of **set screws** in the fitting sockets which grip the pipes (fig. 787).



No. 1

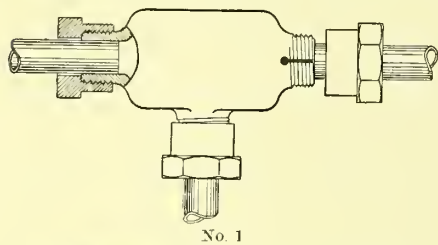


No. 2

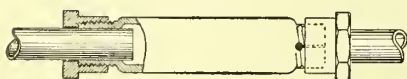
Fig. 788.—Screwed-nipple Connections

No. 1, Tee; No. 2, Straight-through.

A better method is the **screwed-nipple system** of the Simplex Company, shown in fig. 788. In this arrangement the sockets of tees, bends, and other fittings have an internal thread to take the nipple A. This nipple or bush has a smooth hole to take the pipe, and is screwed on the outside at a slight taper, and has also two or three slits or saw cuts. Two pipes can be joined by using a screwed socket or connector and two nipples, as shown in No. 2. It will be seen from this illustration how much larger the connector must be than the pipe. In using these fittings the ends of the pipe must first be cleaned with a file, then the nipple slipped over it and the pipe entered into the socket. Finally the nipple must be tightly screwed home, when the slits and the taper



No. 1



No. 2

Fig. 789.—The Bayliss Grip with Screwed-nut Connections

thread will allow it to close down and grip the pipe. This type of nipple necessitates fittings of a size larger than would otherwise be the case, as

the sockets have to be large enough to take the nipple, which is of course larger in diameter than the pipe itself.

Another form of grip connector is shown in fig. 789. This is known as the **Bayliss grip**, and forms a very sound mechanical job. In this case the sockets are screwed on the outside, and the pipes enter direct into the smooth bore in the ordinary way. The sockets are slotted, and the end of the screwed grip is cone-shaped, so that, on screwing it home, the socket grips the pipe firmly. When tightened with a spanner, this makes a very rigid job, more so even than an ordinary screwed joint, as the pipes will not turn one way or the other.

Two pipes can be joined by means of a socket and two grips, as in No. 2. With the grip form of connection there is not the same risk of splitting the sockets as with the screwed nipple. In the latter case, as the screw is of the

tapered-plug pattern, and enters a socket having a comparatively thin shell, it is not a difficult matter to split the sockets by screwing them up a little too much. There is an advantage in using some form of screw-grip connection in preference to ordinary screwed piping, in that the pipes can be easily broken at any joint in case of need. With the ordinary screwed system this cannot be done except where there is a running socket, and it is frequently necessary to cut the pipe or take a large quantity down in order to make a small alteration. In screwed-piping jobs it is advisable for this reason to make every socket connection a running socket.

A large variety of fittings suitable for conduit work are obtainable, including pendant lampholder and connection boxes; boxes for mounting switches, ceiling roses, and wall sockets; junction boxes; insulating bushes; draw-in pieces; water-tight fittings; distribution boards, &c.; and tools of various kinds for erecting conduits.

Methods of Fixing Iron Piping.—When piping is sunk in plaster or cement, it can be fixed by means of crampets or pipe hooks, just as gas piping is fixed. The same applies to pipes laid between floors and fixed to the sides of joists. More care, however, is necessary in laying electric pipes than gas pipes, owing to the fact that cables have to be drawn through them. For this reason all bends and angles must be as easy as possible. Square elbows should not be used at all. For surface work the pipes may be fixed by means of saddles screwed into wood plugs let into the wall (fig. 790). Large pipes should have saddles with screws on each side of the pipe (No. 2, fig. 790). As already pointed out, it is preferable to leave a little space at the back of the pipes to prevent condensation, and

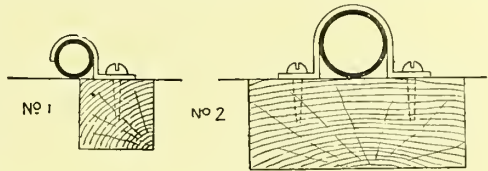


Fig. 790.—Pipe Saddles or Clips

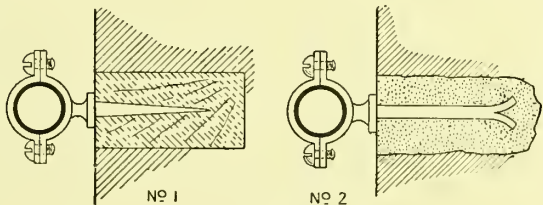


Fig. 791.—Pipe-hangers

No. 1, In Wood Plug; No. 2, In Cement.

in works, factories, corridors, and other places where appearance is not the first consideration, a very good method of fixing is by means of pipe-hangers with removable fronts, as in fig. 791. This makes a neat and workmanlike job, and one which gives a minimum of trouble. Holes should be

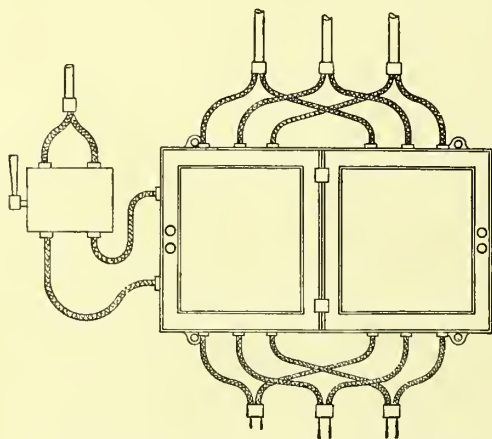


Fig. 792.—Connections to Double-pole Switch and Six-way Distribution Box (Wires exposed)

every pipe, and the cables are all exposed, thus introducing an element of danger from fire and shock. To some extent manufacturers are to blame for this class of work, as they generally leave a bushed hole opposite to each terminal instead of a screwed hole for a pipe, and the wireman naturally thinks he ought to follow out the manufacturer's idea. Fig. 793

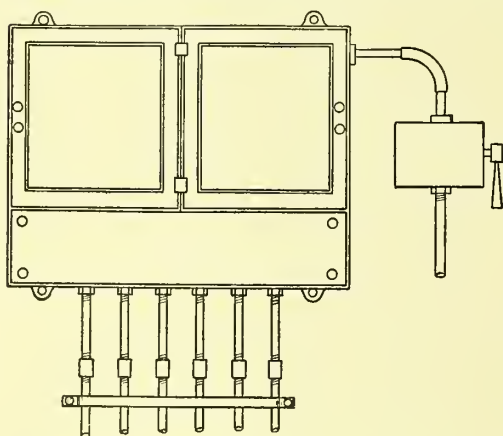


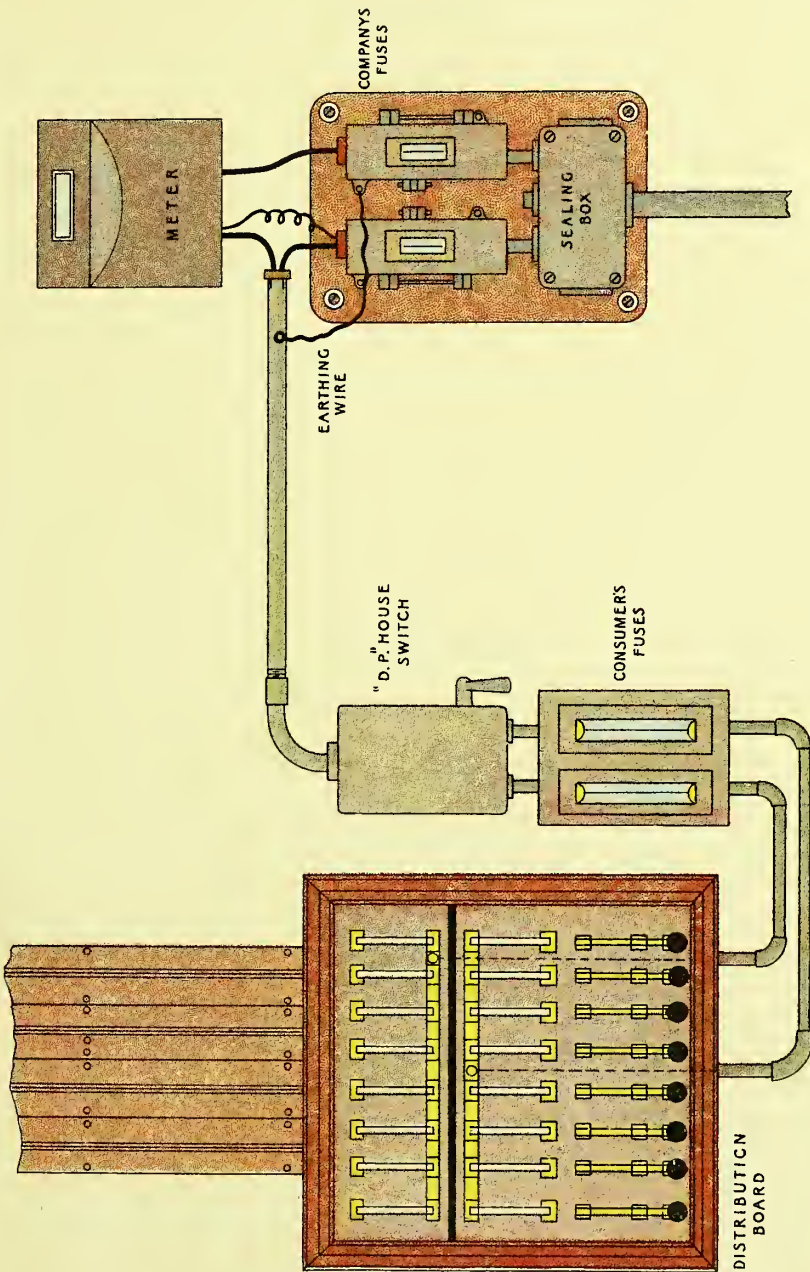
Fig. 793.—Connections to Switch and Distribution Box (Wires enclosed)

cut in the brickwork for each hanger, which should be fixed with cement.

In pipe-work installations the continuity of the system is often broken at the distributing boxes and sectional switches, as shown in fig. 792. Here a double-pole switch and six-way distribution box are shown each in a cast-iron box. The pipes are all cut off close to the boxes, the ends bushed, and the cable brought out into the open and entered into the bushed holes of the switch and fuse boxes. There is a break in the continuity of

is from a photograph of a bit of work in an installation in progress of erection, carried out under the supervision of the writers. Here the makers' bushes in the switch-box have been ignored, and a hole has been drilled in the top and bottom of the box to take the pipe containing the main circuit cables. In the distribution box a chamber for crossing over the wires is cast at the bottom, and each circuit pipe is brought right into this, so that no wires at all are shown.

It often happens that a set must be made in the finishing length of pipe in order to bring it into line with the hole in the box, and as the wires are generally drawn in before the switches and distributing boxes are delivered, it is practically impossible to screw them direct into the boxes. This is not essential, as it makes a good job to fix the pipe by means of two nuts, one



FUSES, METER, HOUSE-SWITCH, DISTRIBUTION BOARD, &c.

inside and one outside the box, as in fig. 794, which shows a side view of the pipe and box.

The fact that the piping and wiring are generally done before the switch and fuse boxes are delivered on the job, often causes considerable difficulty to the wireman. He makes as neat a job as he can of the pipes,

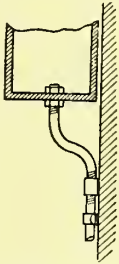


Fig. 794. — Bent-pipe Connection to Distribution Box

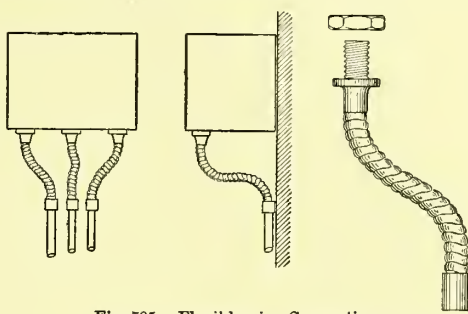


Fig. 795. — Flexible-pipe Connections

spacing them nicely apart, and then finds that the holes in the boxes do not correspond with the lines of piping. Sometimes the boxes are left blank, so that the holes can be marked off to suit the positions of the pipes. This, however, generally necessitates a lot of special work, such as bending short lengths of pipe to templates, and considerable fitting to get them in. In such cases much labour is saved by using flexible metallic piping (fig. 795) to connect the pipes up to the boxes. One end of the flexible pipe must be soldered to a screwed socket to fit the iron pipe, and the other end sweated to a brass ferrule, which is connected to the box by means of a nut on the inside. A number of pipes can be connected in far less time by this means than it would take to bend and screw short lengths of pipe. Flexible metallic pipe will be found very useful also in getting over beams or cornices and the like, but it is important to make a proper job of it by sweating the ferrules or sockets to the ends, and not merely slipping them loosely into the ends of the pipes.

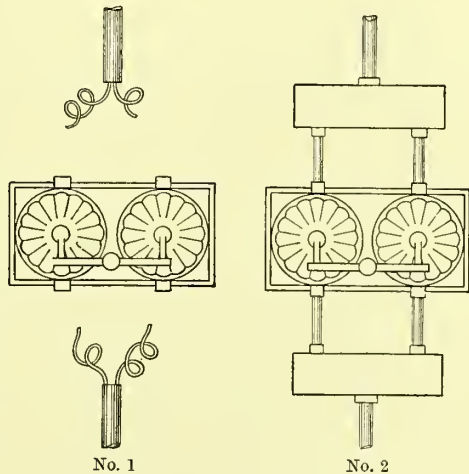


Fig. 796. — Connections to Two Linked Switches

Another awkward bit of work is to connect piping to a double-pole switch, when this consists of two single-pole switches in separate boxes. The problem is shown in No. 1, fig. 796, where there are two switches with four sockets for pipes but only two pipes, one leading to and one away from the switch. A tee piece and two elbows and bits of pipe on each side furnish the most usual solution, but it is an unsightly one, and two dividing

boxes make a much neater job, as shown in No. 2, fig. 796. It is far better, however, when possible, to have both switches mounted on one metal box having a single outlet at the top and bottom.

Tinned-Brass Tubing.—The joints between the various lengths of tinned-brass tubing are made by means of tinned-brass slip sockets, which are soldered to the pipes by means of a blow pipe. The tees, elbows, switch-boxes, &c., are light brass castings tinned over, and these also are soldered to the pipes in the same way, so that the piping system is practically water-tight. It is claimed that owing to the thinness of the pipes there is no trouble from condensation. A further advantage of the system is that bends can be easily made in the pipes when cold.

Mixed Systems.—A mixed system is one in which both metal piping and wood casing are used. It is bad practice to use a mixed system, if all the disconnected pieces of piping cannot be earthed, so that any leakage can be detected.

In a casing job piping is frequently used under floor boards, because it is a little easier to slip a length of pipe in than to take up a floor board and fix casing; the piping is not fixed, but is simply laid on the ceiling laths, or as often as not it is held up by the wires. This is very bad work; it is, in fact, "jerry" work. If both casing and piping are used, they must be properly joined together so as to make a continuous run for the wires, leaving no part of the wires unprotected. Wood casing must not be sunk in plaster, so that if mixed systems were not permissible, wood casing would be very soon entirely superseded by piping.

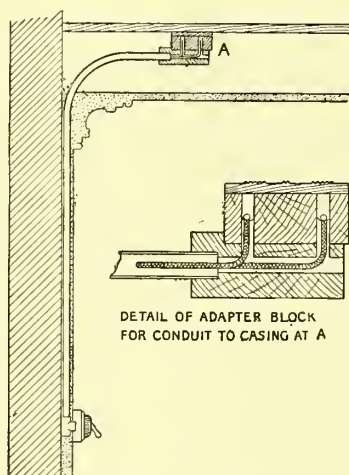


Fig. 797.—Connection of Iron Pipe to Wood Casing

For the sake of appearance, switch wires coming down an inside wall are now generally sunk; and in buildings wired during erection the work would be considerably delayed, if it were necessary to wait till all walls and partitions were plastered before the wires could be run. For this reason tubes for switch wires are generally fixed direct on the brickwork or laths, and are plastered over afterwards. If iron tubes are used on the walls, and casing between the floors, a wood junction piece (A, fig. 797) should be used to join the two systems. The side fillets of the casing are generally too thin to permit the pipe to enter directly into them, and in any case it is better to use a good hard piece of wood to take the pipe, drilled with one hole for the pipe and two for the wires. This can be nailed or screwed to the joist, and makes a good job. It will be noticed that in fig. 797 a tee is shown at the bottom of the switch pipe instead of an elbow. The object of this is to allow any water that may condense in the pipe to drain away and not lodge at the back of the switch. A somewhat different form of adapter block is shown at B, fig. 798.

It is a difficult matter to get an iron bend behind a cornice without

cutting the cornice away. Too often the wires are pulled through cornices with no protection at all, lying in a hole in the plaster. When it is not possible to get either an iron or a lead pipe through, a piece of good rubber hose pipe can be used, as this will adapt itself to an irregular hole better than a metal pipe will. Lead compo pipe is often used in mixed systems for running the switch wires down walls, as it is easier to get round awkward angles. A neat finish to the casing and wood blocks can be made by taking the pipe through a hole in the wood and splaying it over, or making a bell mouth as shown in fig. 799.

In houses or buildings which are occupied it is not generally permissible to cut chases in the walls in order to sink the switch wires, yet the occupiers do not want the casings to be conspicuous in the best rooms. In such a case as this, the switch wires should, as far as possible, be brought down in the halls or passages, and taken through the walls into the rooms behind the switch blocks, as shown in fig. 800.

All pipes or sheathed wires should be kept at least 1 in. away from gas pipes.

Earthing.—The pipes laid on brick walls are generally sufficiently

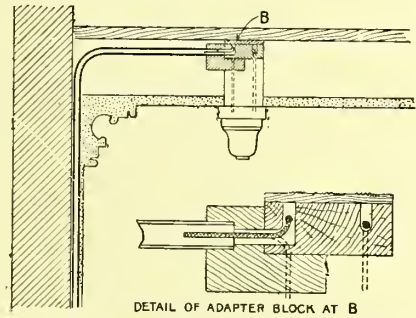


Fig. 798.—Connection of Iron Pipe to Wood Casing (Second Method)

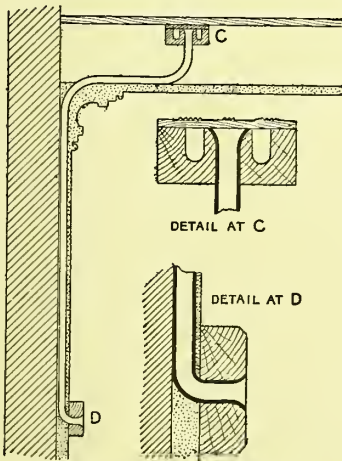


Fig. 799.—Connection of Lead Pipe to Wood Casing

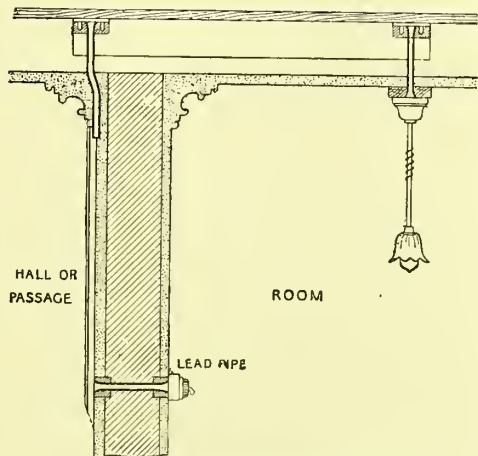


Fig. 800.—Lead-pipe Connections through Wall and Ceiling to Wood Casing

earthed by contact with the brickwork, but when laid in lath or plaster partitions they are practically insulated from earth. Unless, therefore, an earth wire is connected to them, it is very difficult to localize any fault that may develop in them. In a mixed system of this kind the pipes should be earthed, and, to make a really safe job, it is essential to run a bare copper wire alongside the casing, and connect it to each separate

piece of pipe, and earth it to a water pipe, or to the sheath of the supply cable. There are two principal reasons for earthing; the first is to prevent as far as possible anyone receiving a shock, and the second is to prevent the danger of fire. On many systems of supply one pole is earthed. On three-wire systems the middle wire is earthed. If, then, the piping system is not properly earthed, there would be considerable risk in the event of either the positive or negative conductor coming in contact with the pipe, as it would then be practically a live conductor, and anyone standing upon metal or a concrete floor, or in contact with anything earthed, would receive an unpleasant shock, which might cause injury if not death. A further risk is incurred in the event of the piping being discontinuous, as one length of pipe might come in contact with a positive wire, and another length with a negative wire, and these two lengths of pipe would then have a full pressure between them, which would cause a leakage through the building, or perhaps set up an arc, either of which would be dangerous from a fire-risk point of view. It is important then that not only should the piping be earthed, but that it should be metallically continuous, as already mentioned.

The pipe system is generally earthed close to the point of supply, and earthing should be done by means of bare wire equal to the size of the wire inside the tube, where these wires are in sizes not exceeding 7/16. The earth wire should not be connected either to a gas pipe or a soil pipe, or to any other piping but a water pipe. If connected to a soft-metal gas pipe, a spark or leakage of current might, under some circumstances, burn a hole through the pipe and ignite the gas. If the supply cables are lead-covered, the earth wire can usually be attached to the lead covering. The best way to attach the earth wire to the pipe system is to put it between washers, under a screw head, tapped in to one of the metal switch or fuse boxes. In the case of a large wire, sweating sockets should be used. The other end should be attached to a metal clamp, fixed around the water pipe or the main sheath of the supply cable. If the earthing is properly done, it should be possible to ring a bell through two cells connected between any length of pipe on the building and any earthed metal.

Metal-sheathed Systems.—In order to simplify and to cheapen wiring, there are several systems now in use in which no casing or tubing separate from the wire itself is required, as the conductors themselves are covered with a metal sheathing, rendering further protection unnecessary excepting in those cases where the conductors are liable to mechanical injury. Among these systems are the "Stannos", introduced by Messrs. Siemens Bros. & Co., and the Henley wiring system. In the Stannos system the conductors are sheathed with tinned copper by a special process in such a way that the conductors can be very easily bent to any shape required. A certain amount of care is, however, required in bending the conductor to avoid buckling the sheath on the inside curve, and it is important not to bend it about more than is absolutely necessary for fear of fracturing the tube.

The outer sheathing may be used as a conductor, that is to say, the sheathed cables and wires may be used as a concentric system under the following conditions of supply:—

1. When current is generated on the premises, as in country house installations at low voltage.

2. When a double-wound transformer is employed to reduce the pressure on a town supply for low-voltage lamps.

The outer sheathing must not be used as a conductor when an auto-transformer is employed to reduce the pressure, or when taking supply direct from public supply mains, because in both alternating and direct current systems one pole or the neutral is earthed, and the liability to leakage or "short" on an installation is much greater where only one of the poles is insulated.

When used as a concentric system, the wires must not be run under plaster, as this is liable to corrode the sheathing. It must be borne in mind that any corrosion or damage to the sheathing in a concentric system, whereby the continuity of the metallic circuit is interrupted, is liable to set up heating and become a danger. Consequently, although run on the surface, such wiring must be protected wherever likely to be subject to mechanical injury or corrosion.

It is often convenient to combine the ordinary two-wire conduit system with two-wire Stannos branches in positions requiring surface treatment. In such cases the branches should be run from conduit connection boxes provided with brass bushes drilled to take Stannos wires, and the sheathing of the wires should be soldered to the bushes to earth it properly.

Special fittings are provided for ceiling rose and switch points and also for junctions, the arrangement being such that the outer conductor or sheathing is clipped to the base, so that all the sheaths entering the box are metallically connected together: the inner conductors are connected to the terminals in the switch or ceiling rose or other fitting. It is important to see that good metallic contact is made between the sheath and the metal base of the fittings, as a bad connection or break would have just the same effect as a broken conductor in an ordinary two-wire system.

The same class of fittings is required whether the system is used as a concentric system or as an ordinary two-wire system, so that the whole of the sheathing is connected together and can be earthed in the same way as the piping system.

This system is very convenient for surface work, as the conductors can be readily bent over curves and the like, and, being small, do not offer much disfigurement to the decorations.

It is important to bear in mind, when using auto-transformers on this or on any other system for the purpose of reducing the voltage on the lamps, that the installation may be subjected to the full pressure of the supply between conductors and earth, and the quality of the work should therefore be such as to stand this. On a three-wire system, one pole of the installation should be connected to the earthed neutral, and not to the outer or live conductor.

The Henley Wiring System.—A sheathed system of wiring has been brought out by W. T. Henley's Telegraph Co. Works, Ltd., Cable Makers, with a view to overcoming the difficulty experienced with cables sheathed with hard metal, namely, the difficulty of straightening out a sharp bend

that may have been made accidentally or incorrectly, for there is a risk in straightening out such a bend that the metal will part and so reduce the section, besides destroying the watertightness of the system. The faulty portion, too, may heat up if the sheathing is used as a conductor.

The Henley conductor may be either single core or twin, the former type being used for concentric systems; that is to say, when the sheath is used as a conductor, the cable employed is insulated with vulcanized rubber and is then wrapped spirally with a copper tape, the whole being then sheathed with a special lead alloy. With the concentric system only one special fitting is used (see fig. 800a), consisting of a steel screw drilled and tapped through the head to such a depth that a steel stud may be firmly screwed into it. This is provided with nuts and washers, and is for the purpose of attaching a short bare wire to the outer conductor to form the second conductor for the fittings. In alternating systems a spring washer is provided to overcome the risk of the connections working loose.

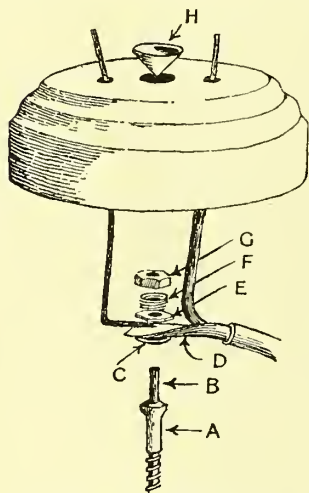


Fig. 800a.--Henley Wiring Special Fitting

After the switch and light points are decided, the bottom half of the H.W.S. screw fitting (A) is screwed into the wall or ceiling at the point fixed: the stud (B) is then screwed into its head, a washer (C) is then slipped on. The fitting is then ready to receive the outer conductor of the cable. The ends of the cables to be finished at this point are prepared in the usual way, the outer conductor (D) being unwrapped from the core, straightened out, and bent back at a point about 1 in. from the finish

of the metal covering. A hole is punched through the double thickness of tape by means of a plier punch: the hole so made is then slipped over the stud, followed by a brass and a spring washer (E and F). The whole is then held securely by the hexagonal nut (G), the wood block being placed over all and held in position by means of the cone-shaped nut (H).

CHAPTER VI

ARC LAMPS

Arc lamps are now divided into two principal classes, the open and enclosed types. Not every arc lamp which is fitted with a globe is an enclosed type of lamp in the sense in which this term "enclosed" is used, nor is every open-type lamp naked—that is, without a globe. The term *open type* means that the carbons are burning in air, and the globes surrounding the arc are merely provided for appearance, for protecting the arc against draughts, and for safety. A lamp of the *enclosed type*, on the other hand, does not burn in air. It is provided with either one or two globes. In

the first case it is known as *single enclosed*, and in the second case it has an inner and an outer globe, and is known as *double enclosed*. The object of the globes in the enclosed type of lamp is to exclude air from the carbons, and thus to enable them to burn for very much longer periods than they would do if in contact with the air.

The open lamp requires a pressure across the terminals of about 50 volts, and burns with an arc of about $\frac{3}{16}$ or $\frac{1}{4}$ in. in length between the two carbons. An enclosed lamp takes about double the voltage, namely, 100 volts, and burns with an arc of $\frac{3}{8}$ to $\frac{1}{2}$ in. in length.

The arc light, as its name implies, gives an electric flame in the form of a small arc, formed between the points of two carbons. It is essentially different, therefore, from the light of an incandescent or glow lamp, which is produced by the heating of the carbon or metallic filament itself. If two carbon rods are held in line, with their ends touching, and current is passed between them, an arc will be formed between the two points on drawing the carbons slightly apart, and the length of this arc will depend upon the voltage that is maintained between the two carbon rods. This is the general principle upon which the arc lamp is based. In the commercial forms of arc lamp certain mechanism is provided, which draws the carbons apart to the required distance as

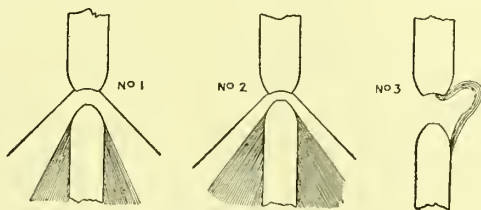


Fig. 801.—Arc Lights

No. 1, Normal Arc; No. 2, Short Arc; No. 3, Flaming Arc.

soon as sufficient current passes through them. There are now so many types of arc lamps that we do not propose to give any detailed descriptions of the mechanism. Those readers who desire more detailed information are recommended to refer to books devoted specially to the subject of arc lamps.

In an open-type lamp the voltage necessary to give a satisfactory and efficient arc is about 45 volts between the carbon points—that is, on the arc itself—and 5 volts are usually allowed for the coils and connections, making 50 volts in all across the lamp terminals. If for any reason the voltage across the lamp is too low, the proper length of arc cannot be maintained, and the amount of light given is enormously reduced with a small reduction in the length of arc, as the carbons are then so close that a large proportion of the light is lost, due to the shadow of the lower carbon.

In continuous-current arcs it is important to see that the polarity is right, the positive lead being connected to the positive pole of the lamp, which leads to the upper carbon. The current thus enters at the top carbon, and leaves at the bottom carbon, with the result that the top carbon burns away in a cup shape, and the bottom carbon to a pointed shape. The cup shape at the top, being at a perfectly white heat, forms a reflector, which throws the light well down, and the lower or negative carbon, being somewhat pointed, allows the light to get away past it.

Arcs.—No. 1, fig. 801, shows roughly the forms of the carbon in a lamp which is burning properly, from which it will be seen that the maximum

amount of light is obtained at about an angle of 45 degrees from the arc. From No. 2 it will be seen how very much the light is reduced by the carbons being too close together owing to insufficient voltage. Besides being closer than they ought to be, the bottom carbon is not so pointed, and therefore keeps off more light even than would be the case if it kept the same shape as shown in No. 1. A short arc generally hisses, and so one is warned of the trouble. If the pressure is too high, the lamp is apt to flame. A long arc, of course, gives a very powerful light, but is very unstable, as currents of air are apt to blow it out very easily. No. 3 shows a long flaming arc, and it will be seen how the hot air rising tends to draw the arc out upwards. If, then, an arc is continually going out, this is at once a sign that there may be too great a distance between the carbons.

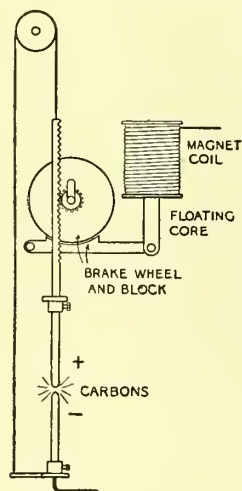


Fig. 802.—Brake Mechanism of Arc Lamp

Principles of Working.—After the arc is struck by the current being switched on, the carbons slowly burn away. In order to maintain the arc, that is, to prevent the carbons burning so far apart that the arc goes out, some form of feeding mechanism is necessary to bring the carbons gradually together as they burn away, and to keep the length of the arc always the same. The types of feed mechanism used may be divided broadly into two principal classes, namely, the brake mechanism and the clutch mechanism. There are, however, other kinds of lamps, but these are not so generally used.

The **brake mechanism** is shown diagrammatically in fig. 802. It consists essentially of a magnet coil, or solenoid, connected up in series with the carbons, and having a loose core suspended in its centre. When the current passes through the coil, this loose core is drawn upwards. Near the coil is a wheel, which is geared up to the upper-carbon holder by rack and pinion. A brake block is fixed on a lever, one end of which is fixed, the other end being attached to the bottom of the moving magnet core. When current is switched on to the lamp, the coil is magnetized and pulls up the floating iron core. This immediately puts the brake on the wheel, preventing it from turning round, and then lifts it bodily with the upper-carbon holder sufficiently to draw the carbons apart and strike the arc. It is then held in this position, and as the brake is on the wheel it cannot revolve. As the carbons burn away the arc becomes longer, thus putting more resistance into the circuit, and consequently reducing the current passing through the lamp. The magnet coil being thus rendered weaker, the core falls slightly, bringing the carbons a little closer together. This operation is repeated each time the carbons are burned away sufficiently to reduce the current perceptibly. In a short time the floating core and the wheel-and-brake attachment are lowered sufficiently to bring the wheel spindle against its limit stop, so that it cannot lower any farther. When in this position any further burning away of the carbons causes the magnet core to

drop a little lower, releasing the pressure of the brake on the wheel; the weight of the carbon and carbon holder is then sufficient to make the wheel slip and revolve slightly, thus bringing the carbons closer together again. The current strength immediately increases, due to the carbons approaching each other, and the brake lever rises and locks the wheel again. As the carbons burn away, this operation is repeated. The movement of the core in normal working is almost imperceptible, as the mechanism is extremely sensitive to slight variations in the current.

The diagram is not intended to show the mechanism of any particular lamp, but merely the principle of working.

In some arc lamps **dash pots** are provided to prevent the lamps from "pumping" or flickering, by which is meant that the arc goes out immediately it is struck, then restrikes and goes out again, and so on. This is due to the lamp being too sensitive. When the arc is struck, the inertia of the parts causes them to overrun their correct position, and the arc is lengthened out until it breaks. A dash pot linked up to the solenoid or striking mechanism makes it sluggish, and so prevents "pumping". Dash pots consist of a fixed brass tube closed at one end, in which a close-fitting piston works. Sometimes they are filled with glycerine, or a mixture of glycerine and alcohol, but in some lamps air dash pots only are used.

Clutch Lamps.—One of the earliest kinds of arc lamp was the Brush Lamp, made by the Brush Company, in which the feeding mechanism was a very simple form of clutch. Most of the clutch lamps now in use may be said to be modifications of this. The clutch was a plain thick brass washer, which loosely fitted the tube carrying the upper carbon. When the washer rested against a limit stop in the horizontal position, the brass tube could slide through it easily, and so feed down the upper carbon. But when the washer was lifted or tilted at one side it gripped the tube, and any further upward movement of it lifted the carbons and struck the arc. Fig. 803 shows diagrammatically the essential parts of the mechanism of a clutch lamp. Here we have the magnet coil, or solenoid, and its floating core as before; but instead of the bottom of the core being attached to a brake lever, as in fig. 802, it is provided with a short arm, the end of which lies under one side of the washer which forms the clutch. When a current is sent through the lamp it passes through the solenoid winding and the carbons. The core is then sucked upwards into the coil, the effect of which is to tilt the washer, which first grips or clutches the upper-carbon carrier and then lifts it, so striking the arc. As the carbons burn away, tending to lengthen the arc, the current gradually weakens, allowing the core to descend and thus maintain the carbon points at their proper distance apart. When the core has fallen sufficiently to

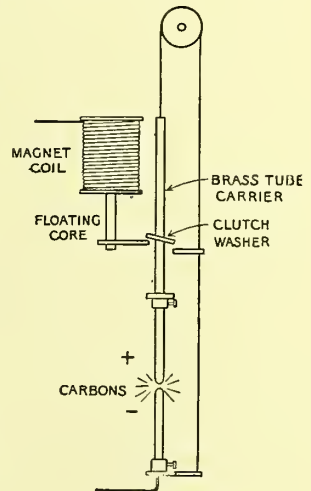


Fig. 803.—Clutch Mechanism of Arc Lamp

allow the lower end of the washer to rest on its limit stop, any further downward movement reduces the angle of canting of the clutch washer, and so releases the grip on the carbon. A point is reached when the carbon begins to slide through the clutch washer and so feed the carbons together. The current at once slightly increases, and lifts the washer again and holds the carbon. When burning perfectly there is an almost imperceptible rise and fall of the core, as the carbon carrier slowly feeds through the washer or clutch.

This is the general principle in which a clutch-feed mechanism works. Different makers have introduced modifications in the form of the clutch and the arrangement of the parts, but the general idea remains the same.

It is obvious that in all lamps working either on the clutch or brake-wheel principle the guide rods or tubes must be perfectly straight and free from dust. Dust causes sticking, and the lamps will then burn irregularly, owing to the feed working in fits and starts.

Poor Light.—When an arc gives a poor light, it is usually a sign that the arc is too short. This, as already mentioned, may be due to insufficient voltage or pressure across the terminals. It may, however, be the result of wear. When the brake block of a brake-wheel lamp has worn down, it does not engage with the wheel quite so soon, when the iron core is pulled up into the solenoid, as it did when it was new. The wheel, therefore, is not lifted so far, and a shorter arc is struck. The remedy is to fix a new brake block, or to pack the old one up a little.

In the case of a clutch type of lamp, the washer or clip, or whatever form the clutch takes, gradually wears on the inside or gripping edges. This results in a short arc being struck, as the round edges do not grip the carbon so quickly as the square edges did when the core is pulled up. There is, moreover, a tendency for the carbon rod or tube to slide through the clutch when it is much worn, particularly when the lamp is subjected to vibration. In the old Brush form of lamp the remedy for this is to turn the clutch washer upside down. This brings those inside edges into play which previously were not used, and are therefore not worn.

Flaring Arc.—When an arc is too long it flares, and is liable to go out. This may be a result of the pressure across the terminals being too high, or the core having too much travel. The latter trouble can generally be remedied by adding a little weight to the bottom of the core.

Burning Down One Side.—This is due to the carbons not being fixed centrally in the holders, or to their not being quite straight. By slacking the carbons and turning them round, a position can generally be found in which the points come together truly in line.

Hissing.—If a lamp hisses and splutters it is a sign that it is burning too short an arc, due either to the pressure being too low or to the striking mechanism needing adjustment. When an arc burns too short, the negative carbon frequently "mushrooms", that is, little projections shaped something like mushrooms form on the end of the carbon, sometimes bridging across the arc and causing spluttering.

Cleaning Arc Lamps.—When fresh carbons are put in, the holders and rods should be carefully wiped with a clean rag or washleather, to remove

carbon dust. The rod should not be oiled or greased, or rubbed down with emery paper.

Cored Carbons.—The positive carbon is generally cored, a soft core being run down the centre of the carbon. This has the effect of keeping the arc central. The positive carbon should be fixed in the upper holder. In order to test whether or not a lamp is correctly joined up, it should be switched on and kept burning for a few minutes. On switching off, the positive carbon is the hotter and keeps red-hot for a longer time than the negative. If the hotter carbon is found to be at the bottom, the connections to the lamp should be reversed.

Parallel Working.—The lamps described up to the present are known as *series-wound lamps*, because the magnet is in series with the carbons. They are only suitable for burning in single parallel across the mains.

When connected in single parallel, each arc lamp must be provided with a *steadying resistance*. The arrangement is shown in diagrammatic form in fig. 804. Let us trace out the circuit of each arc from the positive wire. We first have a switch which cuts current off everything. Then comes the fuse. It is important to connect the switch between the fuse and the

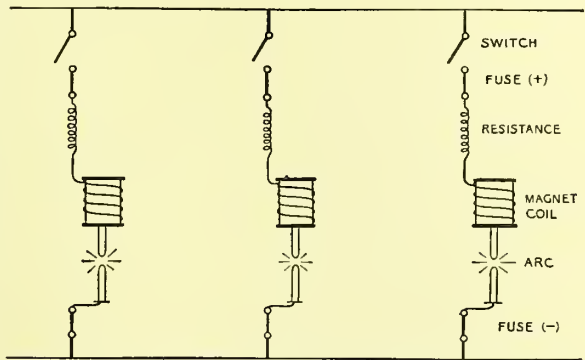


Fig. 804.—Diagram showing Three Arc Lamps in Parallel

live wire, so that pressure can be turned off before putting a new fuse in; this cannot be done if the fuse comes first. Then we have the steadying resistance; after which comes the positive terminal of the arc. The negative terminal of the arc is led away to the negative fuse, one end of which is connected to the negative main.

The object of the steadying resistance is twofold. In the first place it prevents a great rush of current when the arc is first switched on. As the carbons are touching each other, they would form almost a short circuit across the mains if there were no steadying resistance in the circuit. The resistance also serves to steady the arc, as it tones down any variation in the line pressure, and also prevents excessive variations of current which would otherwise be caused by the working of the feed mechanism.

As already mentioned, an open-type arc takes about 45 volts across the terminals. The steadying resistance should absorb about 20 volts; the line voltage, therefore, should not be less than 65 for satisfactory working. Such a low voltage is now rarely used except on board ship. The lowest voltage on ordinary supply circuits is 100 to 110, and this is being rapidly superseded by pressures of 200 volts and upwards. It would be very wasteful to burn open-type arc lamps in single parallel on a 100-volt

circuit, as the steadying resistance would use up more energy than the lamps themselves. Enclosed arcs are suitable under these conditions.

When lamps are run in parallel, the current in the main cables is the sum of all the currents used by the individual lamps. Thus, if in the last diagram each of the three lamps takes 10 amperes, the total current in the main is 30 amperes.

Fig. 804 is not intended to show the actual arrangement adopted in an installation; it is merely a diagram. In practice there would be a distributing switch and fuse box fixed in a central position, from which a pair of cables would be laid to each lamp. For 10-ampere lamps each pair of cables would be of $7/18$ s, and the mains feeding the distribution box would be $19/18$ s. The wiring arrangement is shown in fig. 805. The distribution box would contain on the negative side three fuses, and on the positive side

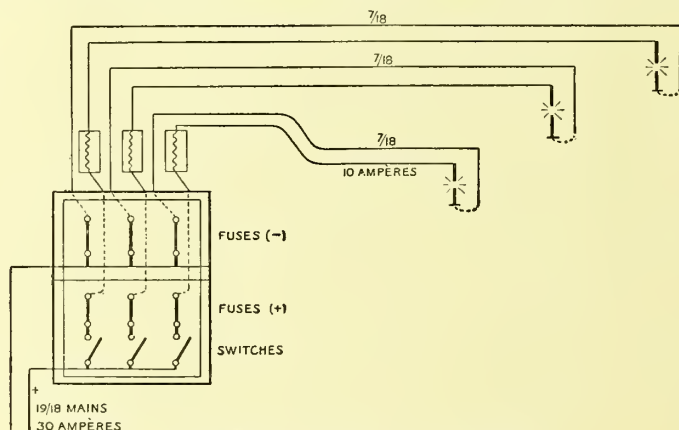


Fig. 805.—Wiring for Three Arc Lamps in Parallel

three switches and fuses. Above the box the three steadying resistances would be fixed, and these would be connected in the positive leads to the lamps.

Multiple Series.—Except on board ship, open-type arc lamps are now rarely run in single parallel, but in what is called multiple series, in which the lamps are joined in series on separate circuits, the circuits themselves being run in parallel from the mains. Thus, if we wish to run six open-type lamps on a 100-volt circuit, we should have three circuits in parallel, each circuit having two lamps connected in series as in fig. 806. The six lamps would take only the same current as the three shown in the last diagram, as when two lamps are connected in series the same current passes through both. The wiring up to the distribution box would be the same, and the general arrangement of distribution box and resistance would be the same, and the same size of cable would be run for the branch circuits. The only difference in the wiring would be that each pair of branch cables would pass through two lamps instead of only one. It will be readily recognized that, when the voltage is sufficient to run two lamps in series, it is much more economical to adopt this arrangement than to run the two lamps in single parallel, as in the latter case double the energy is consumed.

Arc lamps for series working are somewhat differently constructed from those which are used for parallel working. The feeding mechanism of lamps

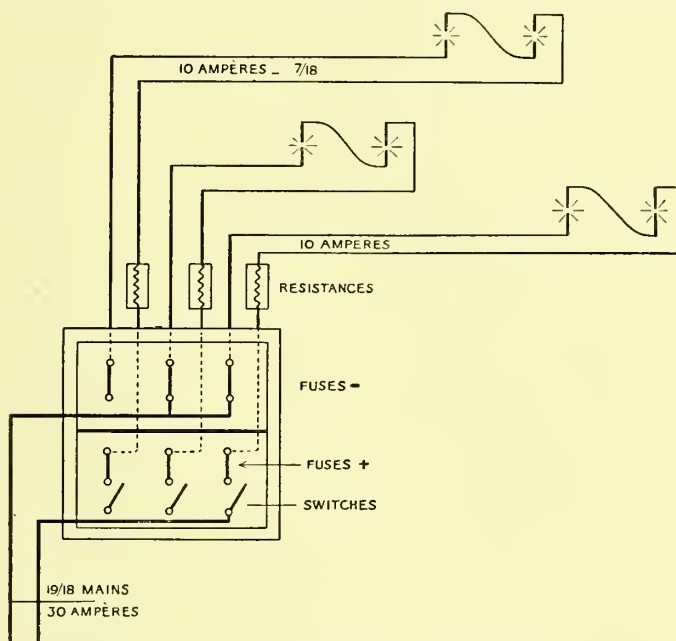


Fig. 806.—Wiring for Arc Lamps in Multiple Series

working in parallel is controlled by the current flowing through the magnetic coil; but if we were to connect two such lamps in series, it might happen that one lamp was burning a long arc, and the other a short arc, yet the current flowing through the two lamps in series would be the same. If the current fell sufficiently to make the lamps feed, the carbons in the lamp burning a short arc might be fed still closer together, and might even touch each other. The result of such an arrangement would be that one lamp would at times take far too much pressure, giving a flaring arc, whilst the other was giving practically no light at all. The feeding mechanism, therefore, for arcs to work in series, must not depend upon the main current passing through the lamps, but must be controlled by the pressure across the carbons. A lamp burning a long arc, and therefore taking more than its proper portion of the pressure, should feed itself; and one burning a short arc, and therefore taking the reduced pressure, should not feed, but be held up until the carbons have burnt away to their proper distance.

In some lamps, therefore, as shown in fig. 807, instead of one magnetic coil there are two; one of these is wound with a thick wire, and is connected in the main circuit—that is, it carries the current which passes through the carbons,—and the other coil is wound by a fine

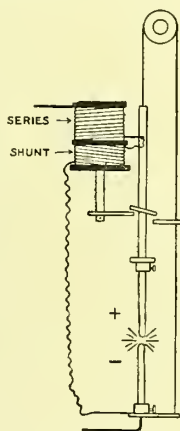


Fig. 807.—Differential Arc Lamp

wire, and is connected up in shunt or as a bypass across the carbons. The windings of the two coils are connected together in such a way that they act in opposition as regards their pull on the core. This differential arrangement is shown diagrammatically in fig. 807. On comparing this with the diagram of the parallel-working lamp shown in fig. 803, it will be seen that practically the only difference is that a shunt coil has been added to the lamp. The action of striking up is precisely the same as in the parallel lamp. When the carbons are touching each other, there is no pressure on the shunt coil, but as soon as the arc is struck, and the carbons are held up by the brake or clutch, a small current is shunted or bypassed through the fine wire coil. As the carbons burn away, the pressure or voltage across them rises slightly, causing more current to pass through the shunt coil; as this current is acting in opposition to the series coil which lifts the carbons, it tends to release the brake or clutch, and allow the carbons to feed—that is, to come closer together. The act of feeding reduces the voltage across the carbons, thus reducing the current in the shunt coils; the series coil then overpowers the shunt coil and tightens up the clutch or brake.

A lamp constructed on this method is called a **differentially wound lamp**, and any number of such lamps will work in series, each lamp feeding quite independently of the others. If one of the lamps should go out, either by the carbon sticking up, or by being blown out, or from any other cause, the whole of the lamps on that circuit would go out, unless some means were provided to prevent this. It is usual, therefore, to provide in these lamps a *short-circuiting device* consisting of a small magnet, which holds up an armature so long as the arc is burning. In the event of the lamp going out, the armature falls away and short-circuits the carbons. This simple arrangement is used on lamps when more than four are burning in series, but it is not suitable when only two or four lamps are in series, as, in the event of one short-circuiting too much pressure is thrown on the others. In this case the automatic device must not short-circuit the lamp, but must switch into the circuit a resistance equal to that of the arc. This is called a *substitutional resistance*.

The **enclosed arc lamp** is, as its name implies, one in which the arc is completely enclosed, and is not in direct contact with the open air, as is the case with the ordinary open type of lamp. It is, of course, impracticable to enclose an arc absolutely, but it can be so enclosed that very little air finds its way into the globe. The earlier forms of enclosed lamps had double enclosures, a small globe about 3 in. in diameter surrounding the carbons, and a larger globe making an air-tight joint with the lamp framework surrounding the inner globe. The object of enclosing the arc is to prevent the carbons burning away so rapidly, as of course oxygen is necessary for the combustion of any material. Whereas an open-type arc, with a single pair of carbons, will burn from 8 to 16 hours according to the length of the carbons, an enclosed arc will burn for upwards of 100 hours without requiring new carbons. This feature not only reduces very considerably the cost of carbons, but also the cost of labour in carboning.

Fig. 808 shows a method of enclosing the arc when a double enclosure

is used. The large globe makes a joint at the top with the framework of the lamp, and has a hole at the bottom large enough to allow the small inner globe to pass through it. The inner globe is fitted at the top with a brass cap having a hole just large enough to allow the top carbon to move up and down freely through it, and is closed at the bottom by means of the bottom-carbon holder. An extension piece from the bottom carries a cap or flange, which makes a tight joint with the outer globe. When the light is switched on, the air in the inner globe

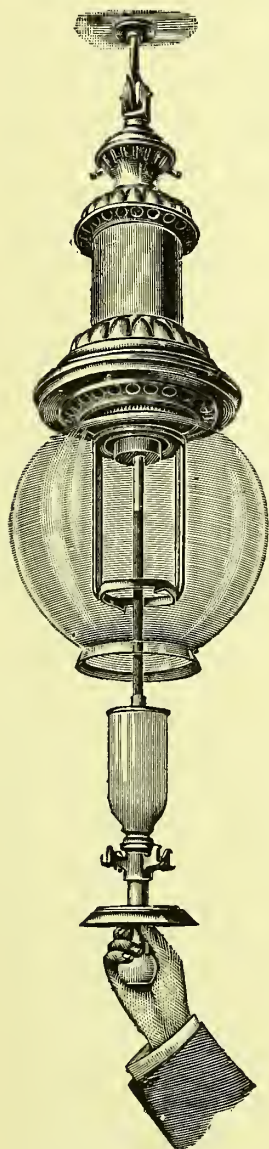


Fig. 808.—Jandus Enclosed Arc Lamp with Two Globes

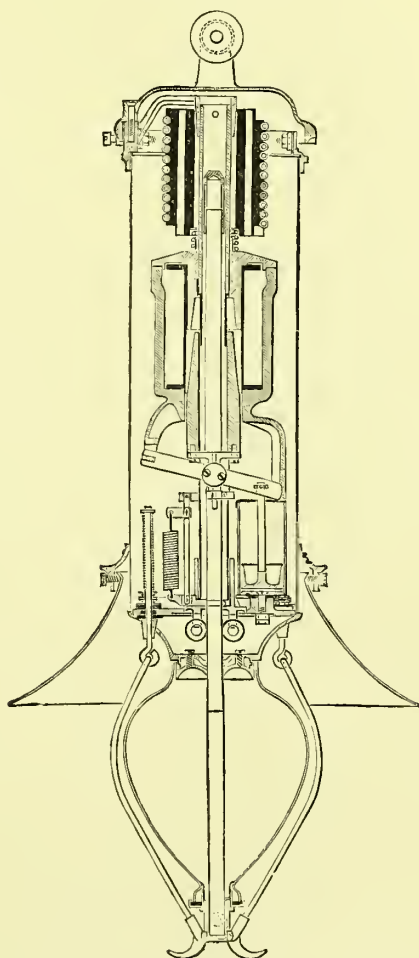


Fig. 809.—Jandus Enclosed Arc Lamp with One Globe

is expanded, and the oxygen is partially consumed, the surplus air, due to expansion, escaping into the outer globe. The cap at the bottom allows an escape of air in the event of the pressure rising, due to the heat. Fig. 809 shows a method of fixing the globe on a single-enclosure lamp.

Enclosed lamps require a **higher voltage** than open-type lamps, and burn with a longer arc. The pressure required across the arc is about 80 volts, and as a steadying resistance is usually embodied in the lamps to absorb about 20 volts, these lamps will burn in single parallel on 100-volt circuits. On 110-volt circuits a little more resistance is required, and usually the resistance is made capable of adjustment so that they will burn on 100 or 110-volt circuits. As the pressures of public-supply mains are now frequently 200 volts and upwards, enclosed lamps have been constructed to burn at these pressures. These lamps are known as **twin enclosed arc lamps**, and are provided with two pairs of carbons in series.

Enclosed lamps can be run in series or in parallel, just in the same way as open-type lamps, and the connections are therefore similar. It must, however, be remembered, that whereas open-type arc lamps in series require about 50 volts each, enclosed lamps should be allowed not less than 90 to 100 volts for satisfactory burning.

The current taken by enclosed arc lamps varies from about 3 to 7 amperes. A 7-ampere enclosed arc lamp corresponds with a 10-ampere lamp of the open type.

Alternating-current Arc Lamps.—Lamps burning on alternating current do not give quite so much light as continuous-current lamps for the same amount of energy. One reason for this is the absence of a definite positive and negative carbon, each carbon being positive and negative in turn as the current alternates. As was shown in discussing continuous-current arc lamps, the end of the positive carbon burns in the form of a hollow crater, so serving as a white reflector to throw down the light. This advantage does not obtain with the alternating-current lamp, and a considerable portion of the light is wasted by being thrown upwards instead of downwards. As the bottom carbon does not burn to a point, as in a continuous-current lamp, a greater shadow is cast, which further reduces the effective illumination. One advantage which the alternating current possesses for arc-lamp work is that there is no need to waste so much energy in resistances. Choking coils can be used in series with the lamps, consisting of coils of wire wound on laminated iron cores, instead of the usual resistance used with continuous-current lamps. These choking coils act as single-coil transformers, and whilst they choke down the voltage just as resistances do, there is very much less loss, because the energy absorbed at one portion of the alternation is given back to the circuit at another portion. It is therefore much more economical, when possible, to use choking coils instead of resistances.

Another advantage possessed by the alternating system is that the arc lamps can be switched in and out singly, when burning in series, without much loss of energy. When a continuous-current lamp is switched out, it is necessary to insert an equivalent or substitutional resistance in the circuit, so that when four continuous-current lamps are burning in series, there is no economy in switching one or more out. When working on alternating-current circuits, economy coils can be used which permit of lamps being switched in and out.

Fig. 810 shows a single-arc lamp running on a 100 or 110 volt circuit.

with an economy coil or compensator in series with it. The coil is divided into two parts, the arc lamp being connected to one end of the coil and to the middle connection between the two halves. The current will pass through the first part of the coil A as shown by the arrow, and then through the lamp and out to the other pole. This first half of the coil acts as a primary of the transformer, producing an equal current in the opposite direction in the other half, B, this current also flowing through the lamp as shown by the arrow. If, then, the lamp is a 10-ampere lamp, about 5 amperes only would flow through the coils, choking down the voltage to the required amount in the first half and then flowing

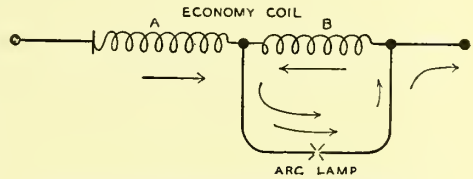


Fig. 810.—Single Arc Lamp with Economy Coil

through the lamp, the other 5 amperes coming from the second half of the coils. The diagram shows the current at one part of the alternation. On the reversal of the current, 5 amperes would flow through the lamp and out through the coil A, which would induce 5 amperes in the coil B, and these would flow round the lamp in the same direction as the current from the main.

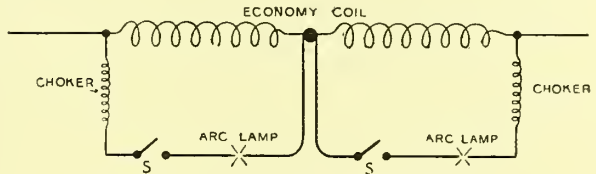


Fig. 811.—Two Arc Lamps with Economy Coil

Fig. 811 shows the same arrangement of coils, but with two lamps connected up, namely, one across each half of the coil. When the lamps are connected in this way very little current flows through the coils, the current simply finding its way through both lamps in series. If, however, one lamp is switched out, the current is at once reduced, and we have the same conditions as shown in fig. 810. This arrangement is not confined to running two lamps in series, but three or more may be run in the same way.

It is generally advisable to place in the circuit of each lamp an adjustable choking coil, so that the voltage of each lamp may be adjusted to the best working pressure.

Both open and enclosed lamps can be run on alternating-current circuits, the enclosed lamp taking approximately double the voltage of the open type. Enclosed lamps are perhaps better than open ones on alternating circuits, as they burn with a longer arc.

A **flame arc lamp** is one in which the carbons are set at an angle, and the arc repelled from the carbon points by means of a magnet, so as to form a flame beneath them. This is shown diagrammatically in fig. 812, where A and B are the carbons, M the repelling magnet, and F the arc flame. The mechanism is not shown, as this varies in different lamps. The fundamental idea, however, is to make the carbons

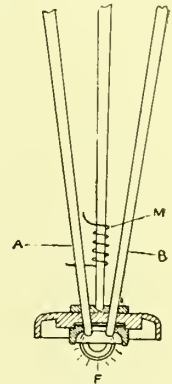


Fig. 812.—Flame Arc Lamp

A and B, Carbons;
F, Flame; M, Deflecting Magnet.

slide down their inclined guides as the arc burns them away. The carbons are of a special character, containing a core impregnated with certain chemicals which give colour to the light, the most effective colour being yellow. There are many lamps burning with the yellow arc which are not really flame lamps, but lamps of the ordinary type with vertical carbons, the carbons being of a special nature. These, however, do not give the same efficient results as the proper flame arc lamps, in which the flame is projected outwards below the carbons. The light given by a flame lamp is about 50 per cent more than is given by an ordinary lamp with the same consumption of energy, and the light is more penetrating owing to its rich colour. A magazine lamp of this type is made by the Oliver Lamp Company, in which a number of carbons are arranged in a somewhat similar manner to the cartridges in a magazine rifle, and these automatically in turn take the place of the burned-out carbons, and in this way the lamp will run for fifty or sixty hours without recarboning.

The **thermal arc lamp** is one in which the striking and the feeding of the carbons are effected by the expansion and contraction of a strip of metal, which is heated by the passage of the current.

CHAPTER VII

GENERATING PLANT

In **electrical installations** in country residences, or in other buildings which are situated at a distance from a town in which there is a public supply of electricity, it is necessary to generate the current on the spot by means of a dynamo and some sort of engine or prime mover. A dynamo can be driven by almost any type of engine which will run at a uniform speed. A uniform speed is essential, as the electric pressure given by a dynamo is practically proportional to the speed at which it is driven. Any variation in speed, therefore, causes a corresponding variation in the voltage or pressure. Electric lamps are very susceptible to changes of pressure, a slight rise or fall producing a great difference in the brilliancy of the lamps. These fluctuations not only cause annoyance, but reduce very considerably the life of the lamps.

In deciding upon the **size and power of an engine and dynamo** for a given installation, the first thing to do is to ascertain as closely as possible the total number of lamps that will ever be alight at one time. It is very rarely the case that the lights in a private house are all on together; but the ratio of the maximum demand to the total number fixed varies with the class of house, and also with the nature of the installation. For instance, some houses are very liberally lighted, whilst in others the lamps are cut down to the minimum possible number. In the latter case the number alight at one time will bear a comparatively large proportion to the number fixed; whereas in a house in which the lights are very liberally distributed the proportion will be smaller. Having

settled, then, upon the maximum number of lights required at one time, the dynamo and engine should be capable of running this number comfortably for a period of about five hours. This would cover the demand on a dark winter's day.

Assume the load to be equal to 100 lamps, each of 16-candle power, and the voltage to be 100. The current required will be 56 amperes, or, to allow a little margin, say 60 amperes; the voltage at the dynamo terminals should be 105, the extra 5 volts being necessary to allow for the loss in the leads and connections.

The electrical horse power given out by the dynamo is found by multiplying the amperes and volts together and dividing the product by 746. In this case, then, the electrical horse power is $8\frac{1}{2}$. The engine, however, must give more than this, as certain internal losses take place in the dynamo and also in the driving belt. The engine should give at least 15 to 20 per cent more power than is actually required in the lamps. For a 100-light installation, therefore, the engine should be capable of developing 10 brake horse power, that is to say, 10 horse power on the shaft. *Brake horse power*, it should be pointed out, is not the same thing as *indicated horse power*. The indicated horse power of an engine is the horse power actually developed inside the engine cylinders, and a certain proportion of this is lost in friction, making the effective or brake horse power about 10 to 15 per cent less than the indicated horse power, the loss depending upon the size and type of the engine. It is important, then, to remember, in ordering an engine, that the horse power required is brake or effective horse power, and not indicated horse power.

It will be seen from the above example that one brake horse power is required in the engine for ten 16-candle-power lamps, and this figure is a safe working figure to take, assuming that ordinary 60-watt lamps are used.¹

Engines used for electric-lighting purposes must always be provided with good **governors** to control the speed within (say) about 3 per cent between full and no load. The best form of governor for the purpose is one which is mechanically driven from the crank shaft without the use of a belt. Belt-driven governors are not very satisfactory for electric-lighting purposes.

Another point which is very essential to satisfactory working is that ample **flywheel power** should be provided on the engine. This applies more particularly to oil and gas engines, as steam engines are usually in the ordinary types provided with sufficient flywheel power to prevent fluctuations in the light. With gas and oil engines, however, the case is a little different, as the flywheels usually fitted to such engines for ordinary work are not sufficiently heavy for electric-lighting purposes. In small sizes, (say) up to 7 horse power, gas and oil engines for electric-lighting purposes are usually fitted with two flywheels, and run at speeds from 270 to 300 revolutions per minute. In larger sizes it is now customary to fit only one large flywheel having an outside bearing, the speeds ranging from

¹ When high-efficiency lamps, such as osram or tantalum, are used, the horse power required will be less, viz. in proportion to the watts per lamp.

230 to 250 revolutions per minute. Vertical oil and gas engines are now made for much higher speeds. The reason that this additional flywheel power is required on oil and gas engines is that the piston only gets one impulse in two revolutions, so that the energy stored in the flywheel by this impulse must be sufficient to keep up the speed during two revolutions, or until the piston gets the next impulse. In the case of a steam engine, the piston gets an impulse at the beginning of each stroke—that is to say, twice in every revolution of the flywheel, so that the amount of energy stored in the flywheel has to suffice for only a quarter of the time which is necessary in the case of gas and oil engines.

When running an electric installation direct from a gas- or oil-driven dynamo, it is a common practice to have a flywheel on the dynamo also, so as to ensure steadiness in the lights. This would not be necessary if the engine itself were sufficiently flywheeled, but in the earlier days of

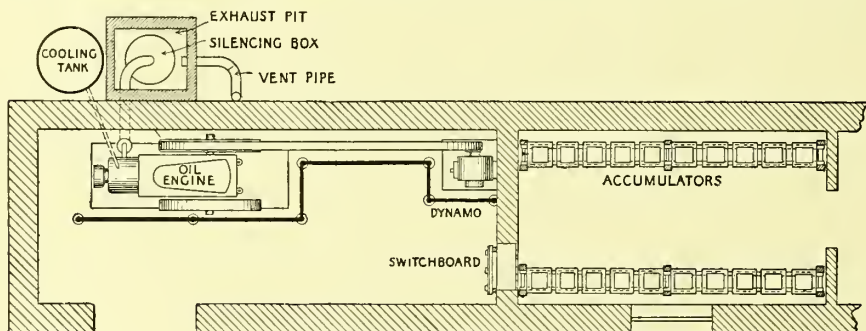


Fig. 813.—Plan of Engine Room and Battery Room

electric lighting this was not the case, and it was necessary to flywheel the dynamo to make up for the lack of flywheel power in the engine. In modern engines, if ordered specially for electric-lighting purposes, the flywheel power is generally sufficient. If a dynamo driven from a gas or oil engine is provided with a flywheel, it is preferable to drive it in such a way that the slack side of the belt is at the bottom and not at the top as in the ordinary way. If run with the slack side at the top, very considerable strain is thrown on the joints of the belt at every impulse of the engine, and trouble due to breaking of joints is almost certain to result. When run with the slack side at the bottom, the belt is allowed to slip slightly over the dynamo pulley at each impulse, and in this way a much steadier drive is obtained.

The general arrangement of an installation with an oil engine, dynamo, and accumulators is shown in fig. 813. When accumulators are employed they should not be placed in the engine room. Not only do the fumes from them corrode or rust the metal work, but the fumes from the engines have bad effects on the acid in the accumulators, so impairing their efficient working.

Gas and Oil.—In estimating the size of meter and gas pipes necessary for a gas engine, the gas consumption may be taken as 25 cu. ft. per brake

horse power per hour for engines of (say) 10 to 15 horse power. For oil engines, a consumption of 1 pt. of oil per brake horse power per hour may be allowed.

Suction gas engines are now largely used for country-house lighting, and give satisfactory results when carefully installed and properly proportioned to the work. The gas is generated in what is called a "producer". This, in appearance, and to some extent in operation, somewhat resembles a greenhouse stove. A hopper is fixed to the top of the producer for the purpose of feeding. The hopper is first filled with anthracite coal or coke, and then closed down by means of a cover; after which a shutter or valve is opened to permit the fuel to fall into the stove or producer. The object of this arrangement is to prevent air being admitted through the top. A water jacket or vaporizer is provided, and is so arranged that, as air is drawn into the fire, it carries water vapour along with it. A trickle of water from a tap keeps the vaporizer supplied, the overflow passing down into the ashpit below the fire bars.

The fuel commonly used is good anthracite coal, as free as possible from tar. Coke also may be used. In starting the fire a blower is used, and when sufficiently hot, as judged by the colour of the smoke or gases issuing from the chimney, the latter is closed, and the gases pass instead through a pipe to the engine. Between the engine and the generator is a scrubber, through which the gases pass. The scrubber consists of a closed cylinder containing broken coke, upon which a water jet or spray falls. The gases, in passing through the scrubber, are cleaned and cooled. Before the chimney is quite closed, the quality of the gas is tested by applying a light to a test cock near the engine. When the gas burns freely with a bluish flame, the outlet to the chimney is closed and the engine is started. As the engine sucks gas from the producer on the suction stroke it produces a draught through the fire, and the air and water, in passing through the white-hot mass, become converted into a form of water gas. The more the engine is loaded, the more explosions and suction will occur per minute, and the smaller the load the fewer the explosions. The gas generated, therefore, is automatically controlled by the load on the engine.

The above general description applies to all kinds of suction plants, but there are differences in detail. If the makers of a plant issue printed instructions for its operation, these instructions should be carefully followed.

It should be remembered that the gas is poisonous, and the room or place in which the generator is placed should be very well ventilated. Owing to the suction principle of working, gas cannot leak from the generator into the air during the time the engine is working, but when the engine is standing it is possible for a dangerous accumulation of gas to take place, unless the cock to the atmosphere is open. In cleaning out the generator great care must be exercised to prevent explosions or suffocation, due to the presence of gas.

Dynamos.—There are now so many good dynamos on the market, and the troubles with them are so few, that it is unnecessary to go into such

detail as regards their maintenance and upkeep as was necessary some few years ago. One of the most important conditions for the satisfactory running of dynamos is that they should be kept clean and dry. If this is attended to troubles will be very few. The two principal troubles that are now met with are overheating and sparking.

By **overheating** we refer to the overheating of the armature or magnet coils, and this may be due to one or more of several causes, the principal being overloading and long-continued runs on full load. When a dynamo is sold for a specified load, it is generally assumed that the full load will not be on for more than four or five hours at a time. For continuous working, a larger dynamo, having a margin of output over and above the actual requirements, should be used.

Another common cause of overheating is insufficient ventilation of the dynamo room. A considerable amount of heat is given off from engines, whether they are worked by steam, gas, or oil, and unless the engine room is well ventilated it becomes so hot as to make it quite impossible for a dynamo to run as coolly and satisfactorily as it ought to do. Dynamos and motors are generally rated to give their full load for five or six hours with a rise of temperature of about 70° F. above the atmosphere, so that if the temperature of the engine room is 70° or 80° , the temperature of the dynamo coils may be anything up to 150° F. This is a temperature which feels very hot to the touch, and it may be assumed that, if the hand can be comfortably held on any part of the windings, the machine is not too hot.

Sparking at the commutator may be also due to a variety of causes, but the more general causes are overloading and the incorrect position of the brushes. There is usually an adjusting handle provided on dynamos, so that the brushes can be set a little forward or backward in order that they may be adjusted to a sparkless position; this position in some machines requires altering to suit the load, although in modern machines little or no alteration should be needed under ordinary working conditions. The commutator should not be allowed to get dirty, or this will produce sparking; it should be cleaned up occasionally by means of a rag and a little paraffin.

If a commutator shows signs of wearing unevenly, the unevenness should be removed by means of a smooth file and glass paper. It is advisable not to use emery paper, owing to the danger of the emery getting into the bearings. If the commutator shows signs of wearing in grooves, the cause may be that the brushes do not cover the whole of the surface. It is advantageous to stagger them slightly so that one set is not exactly in line with the others, and thus every part of the commutator comes into contact with one or other of the brushes. When copper or brass gauze brushes are used the points should be trimmed from time to time, or otherwise they will gradually wear down and cover too much of the commutator surface and cause sparking. The ends of the wires also become hard by the constant friction. When trimmed, these brushes should cover about one and a half to two segments.

Carbon brushes are now very largely used, and, generally speaking, they run with less sparking than metal brushes, and do not require so much adjustment with variations of the load. It is, however, necessary

to see that these brushes take a proper bearing on the commutator. If their ends are flat they will, of course, touch the commutator in one place only; in putting new brushes in, therefore, it is necessary to bed them down properly. This is best done by means of a strip of fine glass paper stretched over the commutator with the glass side outwards. The carbon brush is then held firmly down on to the rough surface, whilst the paper is drawn to and fro over the commutator. In this way the brush can be worn to practically the same radius as the commutator, and after a little running will take a proper bearing.

The tension of the brushes, both carbon and copper, should be carefully adjusted so that the current is properly collected without sparking, and at the same time without the brushes bearing so heavily on the commutator as to cause overheating due to excessive friction.

Belts.—When a dynamo is driven by belt, this should be as pliable as possible, and the joint should be so carefully made that it is almost as pliable as any other part of the belt. If a solid leather belt is used, this should preferably be of the light double-leather pattern, the joint being scarfed, glued, and sewn by the makers. Raw hide and laminated belts are very satisfactory for dynamo driving.

In ordering a belt, the length should first be obtained by passing a string over the engine and dynamo pulleys when the dynamo is set up on the rails nearest to the engine. The length so obtained will be the endless length to which the belt should be ordered from the makers. When a buckle or fastening of any kind is used, it should be of such a form as not to cause any jump when passing over the dynamo pulley, as this tends to cause sparking on the commutator, and to develop what are called “flats”.

Accumulators.—When accumulators are used, either the dynamo must be capable of giving the higher voltage necessary for charging the cells, or an auxiliary dynamo called a *booster* must be used, which is run in series with the main dynamo when charging. Accumulators are cells for the storage of electricity, and when connected together are known as a *battery*.

An accumulator cell consists of a rectangular glass box containing prepared lead plates immersed in dilute sulphuric acid. For special purposes, such as for use on board ship, on vehicles, or in positions where glass would be unsuitable, the boxes are made of teak with a water-tight lead lining, or of ebonite. The capacity of a cell depends upon the number of plates used. The plates are usually rectangular in shape, and consist of a positive and a negative section, the plates in each section being connected together by means of a thick lead strip, the two strips occupying positions at the opposite sides of the cell. The ends of these strips are prolonged to form a tail piece or lug, by means of which adjacent cells are connected together. The positive and negative plates are separated from each other by ebonite or glass rods placed vertically between them, and in small sizes are held together by strong rubber bands or by a wood framework. Nothing of a conducting nature must rest between the plates or join them together in any way; and for the purpose of preventing any sediment touching the plates, teak strips are placed at the bottom of the cells on which the plates are

supported. In larger sizes the plates are provided with side lugs, which rest on the edges of the glass boxes, the plates being supported in this way instead of by means of the bottom blocks. Glass guide rods are fixed at the bottom of the cells to keep the vertical glass rods in position, and side springs of a lead alloy are inserted between the end plates and the sides of the boxes to keep the sections in position, no wooden framework or elastic bands in this case being used. Sufficient space is generally allowed between the plates and the bottom of the cells to hold the whole of the sediment that may be deposited during the life of the plates. This obviates the necessity of ever removing them from the cells before they are completely worn out.

Accumulator plates are of two types—namely, the *pasted* and the *formed*. In the pasted type they consist of a cast-lead grid, the holes of which are filled with a red-lead mixture, which forms what is called the “active” material, the lead grid itself merely serving to hold the active material in position and to form a connection between it and the lead terminal lugs. When such a cell is charged by passing a current of electricity through it, the active material in the plates which are connected to the positive pole becomes converted into peroxide of lead (PbO_2), and that in the plates connected to the negative pole is reduced to pure spongy lead (Pb). When fully charged, the positively-charged plates are of a dark chocolate colour, and the negative plates of a clean slate colour. When giving out current, or discharging, the peroxide plates give up a portion of their oxygen, and the negative plates, on the other hand, become oxidized, so that, if a battery could be completely discharged, both plates would be converted into simple lead oxide (PbO). Accumulators, however, are never discharged to this extent, for two reasons. first, because the voltage or pressure gradually falls as the cells are discharged, and therefore they cannot in practice be discharged to a point at which their voltage is reduced more than about 10 per cent; and secondly, because the complete discharge of cells has a detrimental effect on the plates.

The plates of the formed type are not pasted, but are specially cast with very fine ribs so as to expose a large surface to the acid. The plates are, in course of construction, treated with acids to render the surface soft, spongy, or porous, when they will take up a charge without the necessity of using paste.

During the process of charging, the positive plates (or the active portions of them if they are of the pasted type) absorb oxygen from the acid, the negative plates absorbing hydrogen, and when the plates are almost fully charged these gases begin to come up to the surface in small bubbles instead of entering the plates, finally becoming so numerous as to give the acid a milky appearance; this is a sign to cease charging. Also, during the charging period, the density or specific gravity of the acid rises, and when fully charged this should be about 1220, as shown on the hydrometers, one of which should be provided for each row of cells. Some makers allow higher densities than others, and the printed instructions sent with the battery must be followed.

Overcharging of batteries tends to rot the plates, and undercharging causes them to become sulphated, which shows itself by a whitish appearance on the surface and edges of the plates. Charging at too high a rate causes excessive bubbling, and also has a tendency to rot and break the plates.

The number of accumulator cells necessary for any installation can be found by dividing the lamp voltage by two and then adding 10 per cent to the number. Accumulator cells, when freshly charged, give about 2 volts each, but this voltage gradually falls off as the cells are discharged. To ensure satisfactory working and long life in the cells, they should never be discharged below 1·8 volt per cell, or 10 per cent below their full voltage. The voltage necessary to charge an accumulator is about 2·6 volts per cell; or it may be said that the charging voltage necessary is about 40 per cent more than the lamp voltage. Supposing, then, we have an installation in which the lighting circuit is 100 volts, we should require fifty-five cells ($50 + 10$ per cent), and the charging voltage would be $100 + 40$ per cent = 140. If a single dynamo is used both for lighting and charging, a shunt-regulating resistance would be necessary to permit of the voltage being varied from (say) 105 to 145. For a 200-volt installation the figures would, of course, be doubled, both as regards the number of cells and the charging voltage.

When a **booster** is used for charging, it is connected up in series with the lighting dynamo, and gives the extra voltage necessary for charging, namely 40 volts. By means of a dynamo and booster it is possible to run lights from the main dynamo, which gives 105 volts, whilst charging the accumulator at the same time with the two machines in series, the added voltage being $105 + 40$, namely, 145 in all. When this arrangement is adopted, the shunt regulator for varying the voltage is placed in the shunt of the booster and not in that of the main dynamo, the latter being run at a constant voltage, the booster voltage being varied to give the charging pressure required. The charging pressure varies somewhat with the state of the battery, the full voltage being required only when the cells are nearly full.

It is not necessary here to give full instructions for **battery management**, as these are always sent out by the battery makers and vary to some extent with the type of battery used. The principal points, however, to bear in mind are the following. The dynamo used for charging should be shunt-wound, so as to prevent a reversal of polarity in the event of the battery discharging through it. An automatic switch should be placed in the charging circuit, designed to disconnect the battery from the dynamo when the dynamo volts are too low for charging. The best type of automatic switch to use for this purpose is one which will close the circuit when the voltage is sufficiently high for charging, and which will open it in the event of the pressure falling below that of the battery. When a switch of this type is used, it is practically impossible to have an accident by switching on the dynamo to the cells when the pressure is too low. The method of working in such a case would be to close the main switches, and then to run the dynamo gradually up to its proper speed with the shunt

regulator in its lowest position. When the dynamo is up to speed, and running properly, the shunt regulator should then be gradually brought up so as to raise the voltage, and as soon as the dynamo volts are higher than the battery volts the automatic switch will close the circuit, and charging will commence. The charging current will then be raised by bringing up the shunt regulator until the full charging current is reached. As the cells become more and more charged their voltage increases, so tending to reduce the charging current. The shunt regulator must therefore be brought up from time to time so as to increase the charging voltage and, at the same time, the charging current. When once charging has commenced, the only thing that it is necessary to watch is the charging current, the voltage being immaterial so long as the proper charging current is going into the battery.

An ammeter should always be placed in the main battery circuit, and should be of what is called a "polarized" or centre-zero type, reading on one side of zero for charging and on the other side for discharging. It is detrimental to a battery either to overcharge it or to overdischarge it. It ought to be charged until every cell gases freely, and not to be discharged below 1.8 volt per cell unless by special instructions from the makers.

The battery room, as shown in fig. 813, should be partitioned off from the engine room. The floor should be very strong, to sustain the weight of the battery, and should be floated over with concrete. It is preferable to incline the floor slightly, so that any spilt acid will drain away to a gutter. It is a good plan to paint the floor regularly with whitening, as this neutralizes any acid that may be spilt, or which may drip from the cells. Where large batteries are installed it is a good plan to finish the floor of the battery room with a layer of acid-resisting asphalt.

The cells (fig. 813) should be arranged in rows, and if space is not limited it is convenient to have them all on one level, so that they can be easily inspected. Where this is not possible, strong timber frames should be constructed, rigidly bolted together, and shellac-varnished all over. The cells should then be mounted on insulators on the stands, and, after being connected together, the connectors should be painted with vaseline or enamelled over to prevent corrosion by the acid fumes. The connecting leads from the switchboard to the various cells should be kept clear both of the cells and of the framework, and as far removed as possible from the influence of any acid spray or fumes, as these rot the insulation. The best method is to supply bare copper rods for the connectors, neatly suspended from or attached to porcelain-bobbin insulators. The rods should be well coated with acid-resisting enamel on completion.

Switchboards in connection with generating plants should be placed in a convenient position in the engine room, and, if possible, so that the commutator of the dynamo can be easily seen from the front of the switchboard. Sufficient space should be allowed at the back of the board for examination and for tightening up any connections. Sometimes it is possible and convenient to cut a hole through the wall on which the switchboard is fixed, large enough to permit of access to all connections. Such an arrangement is shown in the engine-room plan (fig. 813). A main switch and fuse must

be provided on each pole of the dynamo, and when there are more than one dynamo, a switch and fuse must of course be provided upon each pole of each dynamo.

Fig. 814 represents a switchboard made for an installation in which two dynamos were used. This is simply a dynamo switchboard, and consists of a positive and a negative panel, separated by an insulating strip shown by the black horizontal line. On the bottom or negative panel two dynamo switches are mounted, connected respectively to the negative poles of No. 1 and No. 2 dynamo. These switches feed through two main fuses on to a main copper bus bar. It will be noted that the fuse comes between the switch and the bus bar, so that in the event of a fuse blowing it is possible to cut off the live connection before replacing it. The top or positive panel contains two similar switches connected respectively to the positive poles of the two dynamos, the current in each case passing through a main ammeter, so that the output of each machine can be measured.

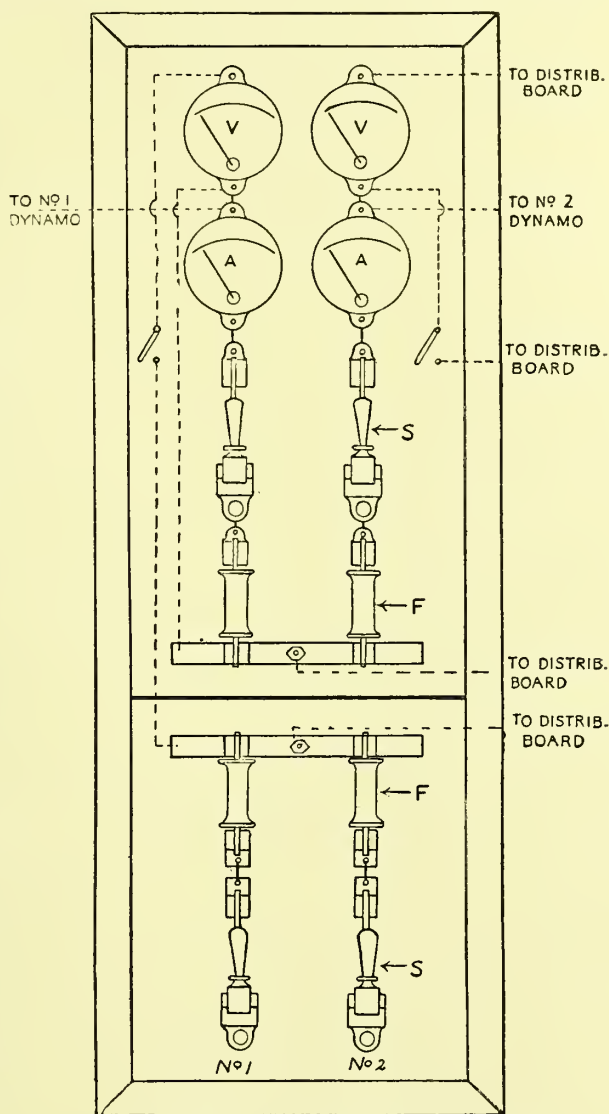


Fig. 814.—Switchboard for Installation with Two Dynamos

A, Ammeter; F, fuses; S, switches; V, voltmeter.

Two *voltmeters* are provided in this instance, so that the volts on the bus bar can be measured, and also the volts at a distant point, (say) the main distribution board, from which a pair of wires are brought back. From the main bus bar a pair of main copper feeders are taken to a main distribution switchboard placed in a central position of the installation, from which the various circuits are controlled.

In fig. 815 a switchboard is shown for use in connection with an installation in which only one dynamo is used, and where the main circuits are controlled from the dynamo room. The board is, as before, divided into positive and negative panels, the lower or negative panel being fitted up with a main dynamo switch, feeding direct through a main fuse connected to a copper bus bar. The main circuit cables leading to the distribution centres are all brought back to this board, the

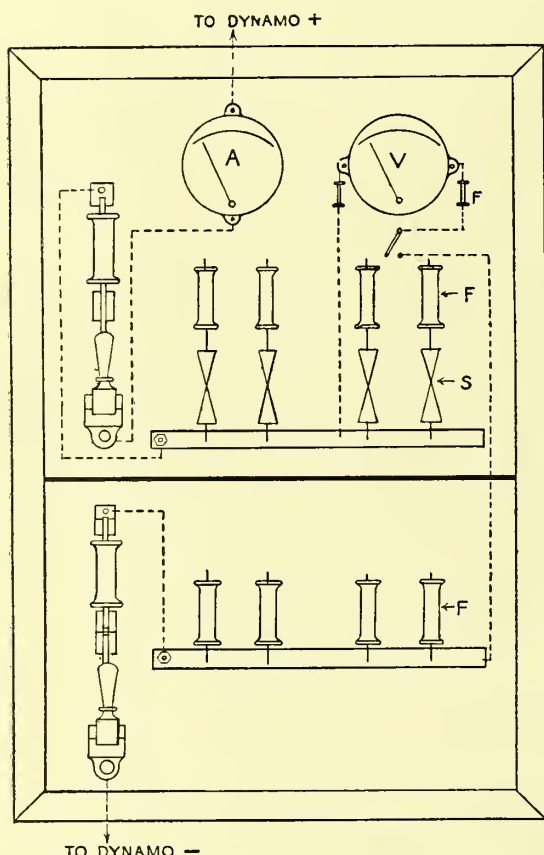


Fig. 815.—Switchboard for Installation with One Dynamo

A, Ammeter; F, fuses; S, switches; V, voltmeter.

negative conductors being connected up to the fuses which are fed from the main bar. The positive or top panel is arranged in a similar way, but in addition to fuses a switch is provided for each main circuit. An ammeter is connected in the main circuit between the main switch and the dynamo; and a voltmeter is connected across the main leads, so that the dynamo pressure can be read before the main switches are closed. It is usual now on installations carrying (say) 200 volts and upwards to fit switches in each pole of the main circuits.

In fig. 816 is shown a switchboard designed for an installation in which accumulators are used. On the lower or negative panel a main dynamo switch is fitted, feeding through a fuse on to the main bus bar, to which the main circuit fuses are also connected.

From the bus-bar connection a circuit is also taken through a similar switch as shown, and through a polarized ammeter on to the negative end of the cells. This ammeter will show the amount of current passing through the battery, and will indicate whether the battery is charging or discharging. A voltmeter is fitted on this panel, and by means of the two-way voltmeter switch, shown between the ammeter and the voltmeter, the pressure of either the dynamo or the battery can be measured. When switched over to the left the voltmeter is connected on to the points A C, which are dynamo leads; and when switched over to the right the voltmeter

joins the contacts B and D, which are the battery connections. On the top panel, which is the positive section, a main dynamo switch is fixed, which is of the two-way pattern, so that the dynamo can be switched direct on to the lamps or on to the battery when charging. It cannot be placed on both at the same time. From the lamp contact, connections are taken to the circuit switches shown, so that when in this position the lamps can be run directly from the dynamo. Above the dynamo

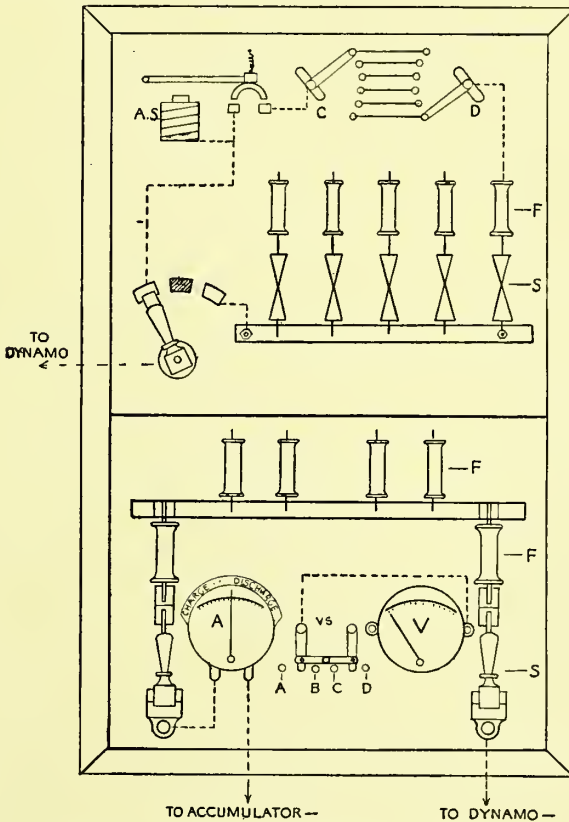


Fig. 816.—Switchboard for Installation with Accumulators

A, Ammeter; F, fuse; S, switch; V, voltmeter; V S, voltmeter switch.

switch a six-way charge-and-discharge battery switch is shown, the discharge side being joined to the main connection which feeds the circuits. The other terminal of the main switch is connected through an automatic switch to the charging side of the regulator, this switch being so constructed that it will only close the circuit at a definite voltage, which is sufficiently high to charge the battery, and that it will break the circuit in the event of the dynamo voltage falling below that of the battery. When the battery is practically exhausted it does not require quite such a high charging voltage as when only partly discharged, and there is, therefore, a little disadvantage in a switch of this nature

which only closes the circuit at a definite pressure, as, in the event of the cells being practically empty, they would take rather a large rush of current when the dynamo circuit was closed by means of the automatic switch.

Fig. 817 shows a switchboard in which two dynamos are used in

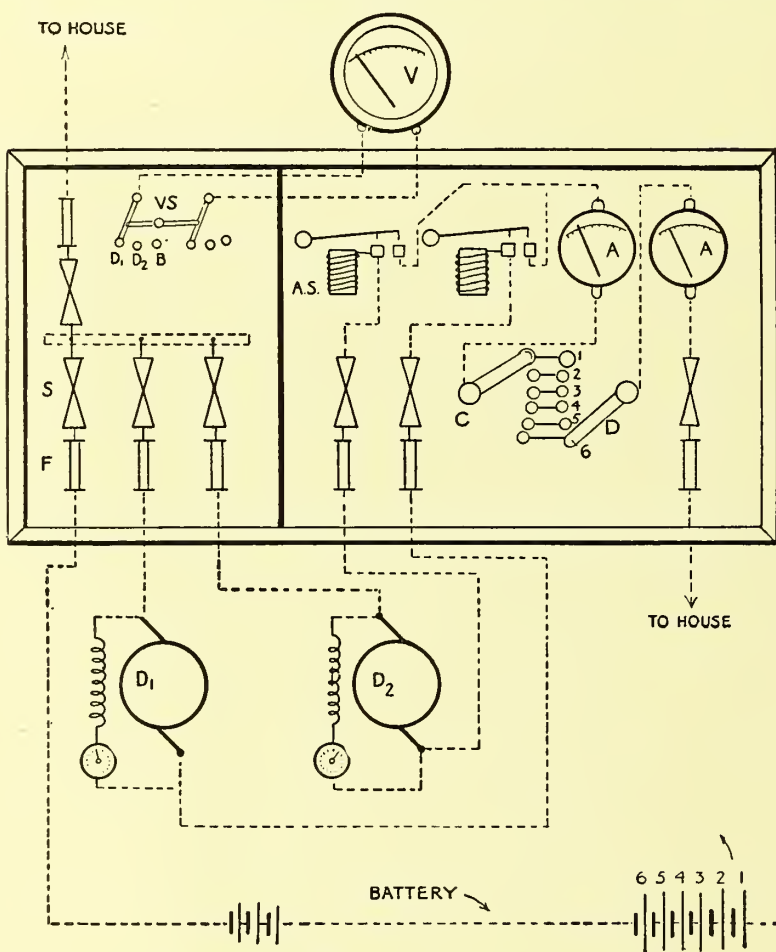


Fig. 817.—Switchboard for Installation with Accumulators and Two Dynamos

D_1 and D_2 , Dynamos No. 1 and No. 2; S, switch; F, fuse; VS, voltmeter switch; A.S., automatic switch; C, charging switch; D, discharging switch. 1, 2, 3, 4, &c., are connected to cells of corresponding number in the battery. A, Ammeter; V, voltmeter.

connection with a battery of accumulators. This board is fixed in the engine room, which is erected at some little distance from the house to be lighted. The board therefore controls the dynamo and accumulator circuits only, and feeds the main distribution board placed in the house. The board is divided vertically into positive and negative sections, the negative side containing two dynamo switches and one accumulator switch. These three switches feed on to a main connection at the

back of the board, the other terminals of the switches being connected through fuses to the negative ends of No. 1 and No. 2 dynamo and the cells respectively. A voltmeter switch is fixed at the top of the panel, by means of which the voltmeter shown above the switchboard can be connected to either of the dynamos or to the cells. On the positive panel are mounted two dynamo switches, one terminal of each being connected respectively to the positive end of its dynamo, the other terminals being connected each to an automatic battery switch, thence through an ammeter and on to the charging side of the six-way regulating switch shown in the centre of the lower half of the panel.

The automatic switches are constructed so that they will close their respective circuits when the pressure upon them is slightly higher than that of the other circuits to which it is intended to parallel them. Thus, if it is intended to charge the battery from No. 1 dynamo, the dynamo and cell switches are all closed and the engine run up to speed. As soon as the dynamo volts sufficiently exceed the cell volts to permit of charging, the automatic switch closes the circuit, and of course opens the circuits in the event of the dynamo pressure falling below that of the cells. Precisely the same action takes place with the other automatic switch, and if both dynamos are running in parallel on to the cells, either of the switches will cut off its dynamo in the event of its pressure falling below that of the other dynamo or that of the cells. The discharging side of the regulating switch is joined through the main lamp switch and ammeter to the main feeder which supplies the house. By this arrangement the dynamo and cells can be run in parallel to supply the lighting, or the dynamo and cells can be used separately if desired. Regulating *rheostats* are provided in the field circuit of each of the dynamos, so that their respective pressures can be adjusted as desired. Each dynamo was in this instance driven by a gas engine, and the accumulators were placed in a room above them, the floor being made watertight.

The water tanks for cooling the engines were also fixed above, alongside the battery room, so keeping the engine room comparatively cool, and at the same time preventing the batteries from freezing in winter time.

CHAPTER VIII

ELECTRIC HEATING

There are many types and patterns of electric heaters now on the market, and greater efficiencies are claimed for some than for others. If, however, we define the **efficiency of a heater** as the amount of heat given off for a definite quantity of electrical energy consumed, one heater cannot be more efficient than another. In other words, one unit of electricity absorbed in any apparatus, whether it be a lamp or a heater or anything else, develops a definite amount of heat, and, no matter

what modifications are introduced into the design or construction of a heater, it is impossible to vary this ratio. On the other hand, it is possible, by specialized construction, to localize or to concentrate the heat, and also to insulate certain parts to prevent radiation. It is possible, therefore, that for special purposes one type of heater or cooking apparatus may utilize its heat to better advantage and give better results than another.

Electric heaters may be divided into two broad classes—namely, *the radiator* and *the convector*. By a radiator is generally understood a heater in which glow lamps are used in front of a reflecting surface; whilst a convector is a heater containing resistance material, the temperature of which is raised by the current passed through it. Convectors are very frequently spoken of as radiators, but it is important to distinguish between the two classes of heater. A radiator consists of heating lamps, and gives off its full heat within a few seconds of switching on the current. The reason for this is that the mass of material to be heated, namely, the lamp filaments, is very small, and quickly acquires a high temperature. On the other hand, a convector, sometimes called a *non-luminous radiator*, generally consists of a metal framework or casing, in which resistance materials are enclosed, such as coils of high-resistance wire, metal films, carbon dust, &c. Considerable time elapses before the mass of metal or carbon is heated up by the current to its full temperature, the time of course depending upon the amount of material to be heated. For similar reasons the luminous radiator loses its heat immediately on switching off the current, whereas the convector retains its heat for a considerable time after the current is switched off.

It will be readily understood from the foregoing explanation that a heater which contains a large body of material is not so suitable for intermittent use as one in which there is a smaller amount of material to be heated. For this reason, therefore, the luminous radiator has become very popular.

It is very important to note the distinction between the effect of **radiant heat** and **convected heat**. It has been said that the heat from glow-lamp radiators is very similar to heating by sunshine. This is true, although it is perhaps not generally understood that sunshine does not heat the air, but only heats the bodies which are opaque to heat rays. If two objects, one black and one white, are placed in the sunshine, the black object will get hotter than the white one, owing to the fact that the former absorbs the heat waves, whilst the latter reflects them. The air transmits heat waves without absorbing them, and therefore is not warmed by them. The same thing applies to luminous radiators. When standing in front of such a radiator a warm glow is felt from it, because the heat rays warm the body upon which they fall. The air, however, is only warmed indirectly, namely, from the opaque substances which are first of all directly warmed by the heat rays. On the other hand, a convector warms the surrounding air by convection or conduction, in the same way that things are warmed in an oven. The difference between heating by a radiator and by a convector is, in fact, similar to the difference between

toasting and cooking. An object placed before a radiator may be toasted on one side by the heat rays whilst practically cold on the other, due to the air being comparatively cold; whereas the same object placed in an oven or near a convector would be warmed throughout by means of the heated air. It will be understood from the foregoing that, whereas there may be no difference between the amounts of heat given off by a radiator and by a convector when absorbing the same amount of electrical energy, their effects may be very different. In dwelling rooms the cheerful look of a luminous radiator is often preferred to the cold look of a convector, just as one might prefer an open fire or gas stove to hot-water pipes.

In some heaters both radiant and convected heat are made use of—that is to say, whilst there are one or two glow lamps to give a cheerful appearance to the radiator, there is also a mass of material introduced which absorbs heat from resistances and transmits it to the air by conduction.

In some convection heaters the construction is such as to produce rapid circulation of the air. This may be accomplished by allowing air to pass through the case containing the resistance coils, which are raised to a very high temperature. By means of such a heater a room may be more quickly warmed than by a solid heater which is maintained at a lower temperature.

For **cooking and boiling** purposes heating is of course done by convection, and it is because the heating surfaces can be brought into such intimate contact with the substances to be heated that electrical cooking appliances are so economical in the use of energy. In the case of gas cooking a considerable amount of the generated heat must necessarily be wasted in the heated products of combustion and the heated air. This waste is always inseparable from any open-flame heater. With electric heating or cooking there are, of course, no products of combustion in the same sense as with gas or coal combustion, and there is no need, therefore, to provide any ventilation for such appliances.

A very simple form of luminous radiator is shown in fig. 818. Two glow lamps are used, which are fitted in special lampholders attached to a metal base. These lamps are usually wired in parallel on circuits up to (say) 230 volts, and switches are generally provided, by means of which one or both lights may be used as desired.

In larger radiators three or four lamps may be used, also controlled by switches fixed on the base of the fitting. These lamps are usually constructed to take 250 watts each, which is equivalent to a consumption of 1 unit in four hours, or $\frac{1}{4}$ unit per hour. On a 100-volt circuit, there-

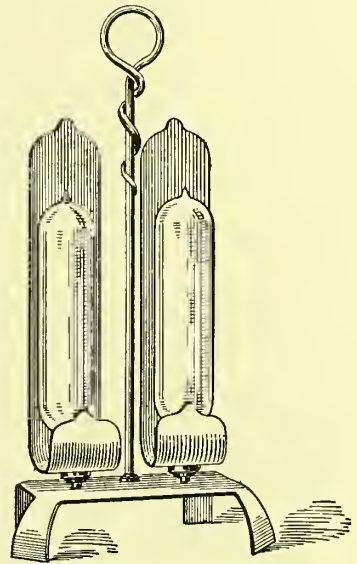


Fig. 818.—Luminous Radiator

fore, the current taken by such radiators is 2.5 amperes per lamp, and on a 200-volt circuit 1.25. A very common size for a moderate-sized room is the four-lamp radiator, and this, when all the lamps are burning, consumes 1 unit of electricity per hour, and the current required would be equal to 1000 watts divided by the voltage. On a 100-volt circuit, therefore, the current would be 10 amperes, and with 200 volts 5 amperes.

These radiators, being portable, are usually supplied with a length of flexible cord, and this should be of ample size to carry the necessary current, and must also be well insulated, and protected with a strong braiding to withstand wear and tear.

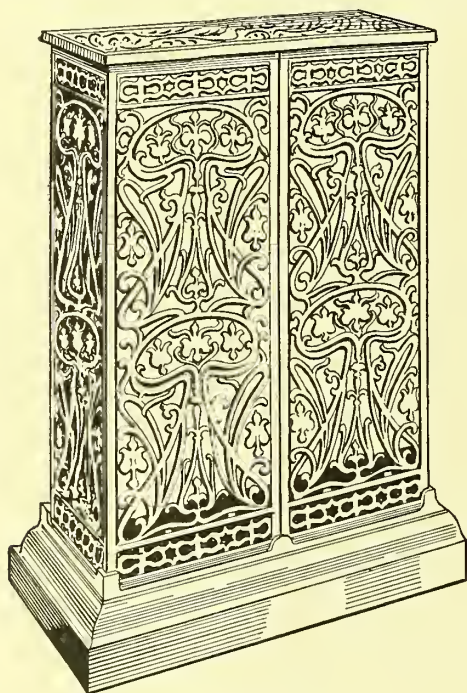


Fig. 819.—Convector Heater

Fig. 819 shows a **convector type of heater** suitable for a house. As mentioned above, convector heaters contain a resistance material through which the current passes, and in which the necessary heating effect is produced. In some convectors, coils or strips of special metal are used. In others, thin films of metal deposited on mica bases are employed, and in others, as in the pattern shown, the resistance material is powdered carbon. The heating sections are constructed of enamelled-iron plates with uralite lining for insulating purposes, packed with powdered carbon, which becomes heated by the passage of the current. These sections are connected together in series or parallel as required, depending upon the pressure of the circuit upon which they are used, and are en-

closed in metal cases, exposing a large surface to the air, and therefore working at a comparatively low temperature. The temperature for which these heaters are constructed is 180 degrees, which is, of course, quite a safe temperature, and one which will not scorch articles laid upon them.

Fig. 820 shows a combined radiator and convector in hand-beaten copper. The two tubular lamps comprise the radiator section, the convector portion of the heater being that shown between the two lamps. The tubular lamps are controlled by separate switches, and the convector, when working alone, is illuminated by two ruby lamps, these being controlled by the central switch. The convector, which is in two sections, is controlled by the two switches shown alongside it on the central panel. The ruby lamps are only intended for use when the radiator lamps are switched out.

According to the revised **Wiring Rules of the Institution of Electrical**

Engineers, issued April, 1907, lampholders for heaters must be specially designed if required for currents above $1\frac{1}{2}$ ampere. The sub-circuits for small heaters must not carry more than 15 amperes on pressures up to 125 volts, nor more than 10 amperes from 125 to 250 volts, and they must be protected by a fuse on each pole. They must not be placed in close proximity to combustible materials unless suitably protected, and must be independently controlled by a switch on the live side of the connector, the connectors being so arranged that the live end of the coupling is not exposed to accidental short-circuiting or injury. When heaters or heating apparatus take more than 10 amperes they must be controlled by a switch and a fuse, or by a hand-grip fuse, or by a circuit breaker on one conductor, and by one of these devices on the other conductor. All radiator circuits must be protected by a fuse on each pole, and by a wall switch in each room in which they are placed.

It is usual to run **separate circuits** from the supply terminals for heating circuits, as special rates are generally given by the supply authorities, necessitating, of course, a special meter in the circuit.

The same general rules apply, of course, to all heating apparatus, whether used for heating, or for cooking, boiling, or other purposes.

A variety of electrical heating apparatus may now be obtained, the most common being electrical kettles, curling tongs, hot plates, and smoothing irons. In using kettles, stewpans, or other apparatus which are intended to be used with water, it is important to remember that, if the current is switched on to them when dry, they will quickly attain a dangerous temperature and probably burn out.

As regards laundry irons also, the current should not be left on when the irons are not in use. An ordinary iron takes a few minutes to attain the required temperature for use, but when once hot it is essential to keep it in use while the current is on, as otherwise it becomes overheated and may burn out. For the same reason an iron with the current on should not be left standing on any

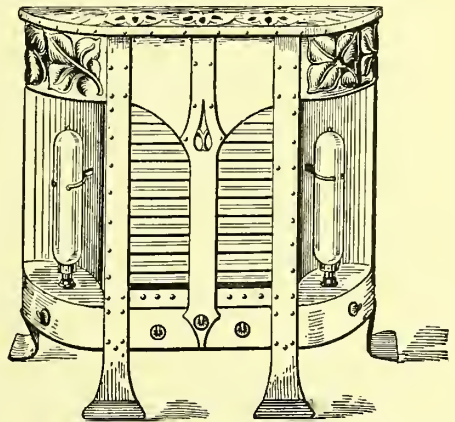


Fig. 820.—Combined Convective and Radiator

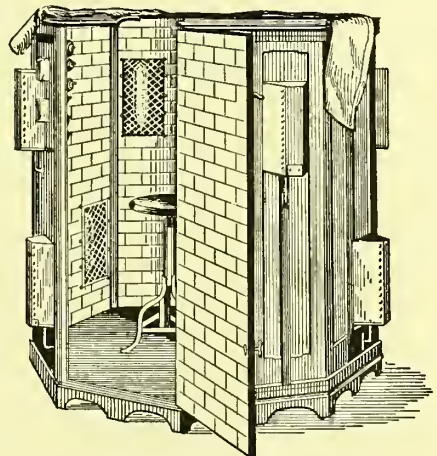


Fig. 821.—Dowsing Solarium

delicate laundry material or on a billiard table, as unless moved about over the cool surface of the material the iron will become overheated and scorch it.

Electric heating has also been largely adapted to **therapeutic purposes**, such as light and heat ray baths. The Dowsing "solarium", or electric sun bath (fig. 821), is constructed in the form of a cabinet, in which the whole body, except the head, can be acted upon by radiant heat and light from lamps and copper reflectors specially arranged. The apparatus is, of course, a kind of portable Turkish bath, and in country houses, hospitals, clubs, hydros, &c., appears to have met with considerable favour, as it possesses the advantage of all electrical appliances in that it need be prepared only when wanted and consumes energy only when used. The current required is about 12 to 16 amperes at 100 volts, or half this at 200 volts. The consumption in fifteen minutes (the usual duration of a bath) is half a unit.

**SECTION XII.—HOT-WATER AND STEAM
WARMING APPARATUS**

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SECTION XII.—HOT-WATER AND STEAM WARMING APPARATUS

CHAPTER I

HEAT

Heat is not a material substance, neither has it weight, but it is a form of energy capable of being transformed into work. The principal sources of heat are the sun, friction, and chemical action.

If a substance is subjected to the action of heat, changes will take place in (1) its temperature, (2) its size, and (3) its state.

Temperature is not the same thing as heat, but is simply the condition of a substance with respect to heat. Suppose that a heating installation holds 1000 gal. of water, which is raised to a temperature of 180° F.; also suppose that 1 gal. of water is heated in a small tank to 180° F. In each case the temperature recorded is the same; but it is obvious that the water in the heating installation will contain 1000 times as much heat as that in the tank. A thermometer simply records temperature, and does not indicate the quantity of heat that a body contains.

The transference of heat from body to body is performed in three ways, viz. by conduction, by convection, and by radiation.

Conduction.—A practical illustration of conduction is the transmission of heat through a boiler plate which is in contact with fire on one side and water on the other. Different substances have different powers of conducting heat, and those which easily transmit heat are called good conductors, whilst those which offer considerable resistance to its passage are termed bad conductors. Water and air are bad conductors of heat. The metals are the best conductors of heat, but some possess greater conductivity than others. The relative conducting powers of metals given by different authorities vary considerably, but the differences have little or no effect upon the amount of heat emitted from either hot-water or steam-heated surfaces. The more important matter is to get the heat into and away from the surfaces; in other words, the resistances to the transmission of heat are far greater at the surfaces of the material than the resistance offered by the thickness of the material itself.

Table I gives the relative conducting powers of different materials compared with gold.

TABLE I.—CONDUCTIVE POWERS OF SUBSTANCES

Gold	= 100	Cast Iron	= 56·2	Lead	= 18
Silver	= 97·3	Wrought Iron	= 37·4	Fire Brick	= 1·14
Copper	= 89·8	Zinc	= 36·3	Water	= 0·9
Brass	= 74·9	Tin	= 30·4		

Convection.—This mode of transmitting heat is confined to liquids and gases, and is the result of the movement of minute particles amongst themselves, owing to their difference of density. The heat from the boiler of a hot-water apparatus is conveyed through the whole series of pipes and radiators by convection currents. The air of a building is also largely heated by convection, owing to the air currents coming in contact with the heating surfaces, or with walls and other objects which have been heated.

Radiant heat differs from conducted and convected heat in that it is transmitted in straight lines, and does not appreciably warm the air through which it passes. The intensity of radiant heat varies inversely as the square of the distance from the point of radiation; thus the intensity of heat 2 ft. from its source is only one-quarter of that 1 ft. away, and 3 ft. away one-ninth, and so on. The direct heat from an open fire and the sun is radiant heat, and the fact of the rays moving in straight lines is proved by the ease with which they are intercepted by objects in their path.

The amount of heat radiated by any surface depends chiefly upon the nature and arrangement of the surface, and the relative amounts of heat emitted and absorbed by a surface are practically the same.

The following table gives the relative radiating values for different substances:—

TABLE II

Lampblack	= 100	Wrought Iron (plain)	= 53
White-lead	= 100	Lead	= 19
Water	= 100	Copper	= 12
Paper	= 98	Silver	= 12
Glass	= 90	Brass, roughly polished	= 11
Cast Iron (plain)	= 60	Brass, highly polished	= 7
Silver and copper, highly polished = 3			

Table II shows that the heat given off by radiation depends not only upon the kind of metal, but also upon the roughness or smoothness of the surface. Cast iron is a good material for heating surfaces, and the amount of radiant heat given off can be increased by painting it with oil paint or lampblack. As radiant heat, however, represents one part only of the heat transmitted by a heating surface, the increased efficiency due to painting is comparatively small.

CHAPTER II

PRINCIPLES OF CIRCULATION IN HOT-WATER APPARATUS

Circulation or movement amongst the molecules or particles of which water is composed is due to the fact that, volume for volume, heated water is of less density than cold. If heat is applied at the bottom of a vessel, about its centre, the tendency is for the heavier particles to sink by the sides of the vessel, while the heated particles rise from the centre, as shown in fig. 822. Circulation is effected by cooling as well as by heating water.

The circulation of water in a heating system is similar in principle to that shown in fig. 822, the difference being that the colder water is returned by a separate pipe or pipes. Circulation takes place in a heating apparatus as soon as the two columns of water which constitute the flow and return differ in weight. This difference in weight is sometimes termed the **motive power of the circulation**, and the motive power required to circulate water through a simple heating system is very small. This is a great advantage, for cases frequently occur where it is only possible to obtain very low motive powers, especially in the warming of horticultural buildings.

There are several means by which the motive power can be increased. One method is to take the flow pipe, directly it leaves the boiler, to a high level, from which it is returned by way of the heating surfaces to the boiler. Another way is to cool the water further in the return, either by increasing its length or by artificial means. The extent to which either of these modes can be employed will depend largely upon the kind of building under consideration.

The table on p. 78 is useful for calculating the velocity of water flowing through hot-water pipes.

Velocity of Circulation.—The rate at which water circulates through pipes depends upon the motive power, the sizes and lengths of the pipes, the number and form of bends, and the kind of fittings used. When the velocity of circulation is known, the sizes of the mains and branches required to do a specific amount of work can be ascertained.

To calculate the precise velocity would be very difficult, as many factors

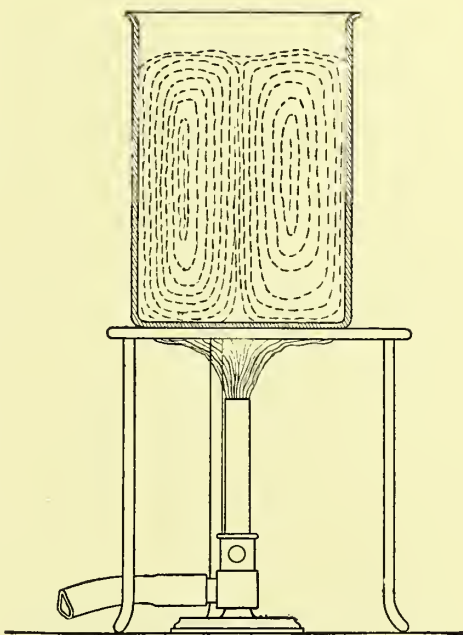


Fig. 822.—Circulation of Heated Water in a Vessel

TABLE III.—WEIGHT OF WATER AT DIFFERENT TEMPERATURES

Temp. Deg. Fahr.	Weight Lbs. per Cu. Ft.	Weight Grains ¹ per Cu. In.	Temp. Deg. Fahr.	Weight Lbs. per Cu. Ft.	Weight Grains ¹ per Cu. In.
60	62·37	252·63	157	61·06	247·31
70	62·31	252·42	160	60·98	247·03
80	62·23	252·07	165	60·87	246·54
90	62·13	251·65	170	60·77	246·19
97	62·06	251·37	172	60·73	245·98
102	62·00	251·09	175	60·66	245·70
107	61·93	250·88	180	60·55	245·28
112	61·86	250·60	182	60·50	245·07
122	61·70	249·90	185	60·44	244·79
127	61·61	249·55	192	60·27	244·09
132	61·52	249·20	197	60·15	243·67
137	61·43	248·85	202	60·02	243·11
142	61·34	248·43	207	59·89	242·62
147	61·24	248·08	212	59·76	242·06
152	61·14	247·66			

require to be taken into consideration; but a simple rule for determining the velocity can be formulated to give results sufficiently accurate for ordinary work. The velocity, when frictional resistances are omitted, can be obtained by the formula—

$$v = \sqrt{2gH} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Where v = velocity in feet per second.

„ g = acceleration due to gravitation = 32·2.

„ H = height in feet.

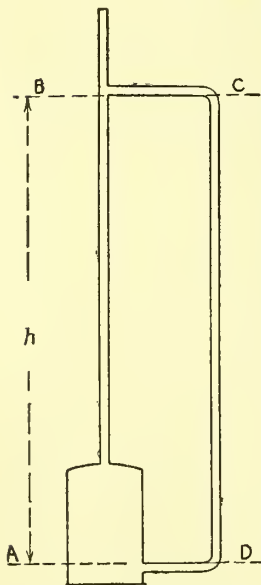


Fig. 823.—Simple Circulation

The formula, as it stands, does not give the velocity of circulation directly, but assumes that it will be equal to that acquired by a weight or body falling freely by gravitation from a height (H). The relation between the circulating head (h) and the direct height (H) requires to be ascertained. The method of doing this is shown in the example below.

Let fig. 823 represent a simple circulation; the difference in weight of columns AB and CD will constitute the motive power of the circulation. Assume the average temperature of the water in columns AB and CD to be 182° F. and 172° F. respectively. If, now, we imagine a portion of the water, say 1 sq. in. in section, circulating without friction through the pipes, their actual areas in such a case need not be ascertained. From Table III it will

¹ Divide the numbers in this column by 7000 to obtain the weight in pounds per cubic inch.

be seen that 1 cu. in. of water at 182° F. weighs 245·07 grains, and 1 cu. in. at 172° F. 245·98 grains; $245·98 - 245·07 = \cdot 91$ grain difference at the given temperatures. Let the ascending and descending columns (fig. 823) be each 5 ft. in height, or $5 \times 12 = 60$ in. = h . The difference in weight of the up and down columns, where each has a sectional area of 1 sq. in., will equal $\cdot 91 \times 60 = 54·6$ grains, and this represents the motive power of the circulation. As there are 7000 grains to 1 lb., the difference in weight of the two columns = $\frac{54·6}{7000}$ lb. The weight of a column of water, 1 sq. in. in section and 2·31 ft. long, is 1 lb.; therefore the height (H) equivalent to the circulating head (h) in the problem = $\frac{54·6 \times 2·31}{7000} = \cdot 018$ ft.

From the formula $v = \sqrt{2gH}$ the velocity can now be obtained; substituting values for g and H (the former may be considered a constant which equals 32), $v = \sqrt{2 \times 32 \times \cdot 018} = 8\sqrt{\cdot 018} = 1·073$ ft. per second, or $1·073 \times 60 = 64·4$ ft. per minute.

This velocity may be found in a more direct manner by the following:—

$$v = 8\sqrt{\frac{(W - w) \times h \times 2·31}{7000}} \quad . \quad . \quad . \quad (2)$$

$$\text{or } v = 8\sqrt{(W - w) \times h \times \cdot 00033} \quad . \quad . \quad . \quad (3)$$

Where v = velocity in feet per second.

„ W = average weight in grains of a cubic inch of water in the return pipe.

„ w = average weight in grains of a cubic inch of water in the flow pipe.

„ h = height of circulating pipes in inches.

As the rules already given do not take friction into account, a large deduction from the calculated velocity must be made. When the piping of a system is very long, and only a small circulating head is available, frictional resistances will be great, and formulæ (1) to (3) will give results as much as 80 per cent greater than would actually be obtained in practice.

The general formulæ for finding the discharge of water through main pipes are not suitable, without modification, for heating work, as the head in the former is direct, whilst in the latter it is indirect. There is also greater mobility amongst the particles of hot than amongst those of cold water.

The following formulæ are given for calculating the velocity of flow in ordinary hot-water heating apparatus. For pipes less than 4 in. in diameter the rule becomes—

$$v = \sqrt{\frac{d \times \cdot 16 \times (W - w) \times h}{l}} \quad . \quad . \quad . \quad (4)$$

For pipes 4 in. in diameter and over—

$$v = \sqrt{\frac{d \times \cdot 2 \times (W - w) \times h}{l}} \quad . \quad . \quad . \quad (5)$$

Where d = diameter of pipe in inches.

„ l = length of pipe in feet.

The remaining symbols are as before.

To allow for friction due to changes of direction, the length of piping can be increased by adding values which vary according to the bends and fittings used. For each "square" (*i.e.* quadrant) bend allow 4 ft. of pipe, round elbow 8 ft., obtuse bend 3 ft., tee 12 ft., and diminishing connection 10 ft.

Example.—Let fig. 824 represent a simple system of hot-water apparatus, the piping of which is 470 ft. in length and 3 in. in diameter. If 40 ft. extra are allowed as equivalent resistance to that offered by bends, the total length of piping which will enter into the calculation will be $470 + 40 = 510$ ft. Let it be assumed that the average temperatures in the flow and

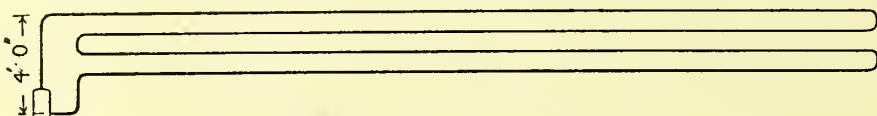


Fig. 824.—Diagram illustrating Velocity of Circulation

return pipes are 175° F. and 152° F. respectively, and the head which causes movement 4 ft. Applying formula (4)¹—

$$v = \sqrt{\frac{3 \times .16 \times (247.66 - 245.7) \times 48}{510}}$$

$$\therefore v = .29 \text{ ft. per second or } 17.4 \text{ ft. per minute.}$$

Suppose the circulating head had been 30 ft., and the temperatures, diameter, and length of piping as above,

$$\text{Then } v = \sqrt{\frac{3 \times .16 \times 1.96 \times 360}{510}}$$

$$\therefore v = .81 \text{ ft. per second, or } 48.6 \text{ ft. per minute.}$$

The effect of increasing the circulating head is clearly shown.

Dipping or Trapping Pipes.—When piping a building it is occasionally necessary to dip pipes under doorways and passages, &c. Dips should be avoided as far as possible, but it is not always convenient to dispense with them. Where a dip or trap is not very deep, the circulating head² of the system in many cases is sufficient to circulate the water through these obstructions; but where the head is not sufficient, it must be increased. Sometimes it is desirable to heat a radiator or coil below the level of the boiler. The best place for dipping a pipe is on the return, and as near as possible to the boiler.

Fig. 825 shows what effect the fixing of pipes below the boiler has upon circulation. In No. 1 the boiler is fixed at the lowest point, and by spacing the pipes into equal portions and marking on the degrees as shown, the difference in weight of the ascending and descending columns can be approximately found. The decline of temperature would not actually take place at anything like the rate shown, and the heat emitted

¹ The values of W and w are obtained from Table III.

² The circulating head is the vertical distance between the highest point of the flow pipe and the return connection to the boiler, when the latter enters the boiler at the level of the fire bars.

by the return pipe for a given distance would be less than that given out by the flow pipe for an equal distance. Equal spacing, however, is sufficiently accurate for ordinary work, as any inaccuracy is usually on the right side.

The circulation in No. 2 is carried below the level of the boiler. The water in column EF is heavier than an equal height of that in the descending column CD, owing to the former having lost more heat. A large portion of the power available in column CG over that in BF is absorbed in displacing the water in EF. The water will circulate through

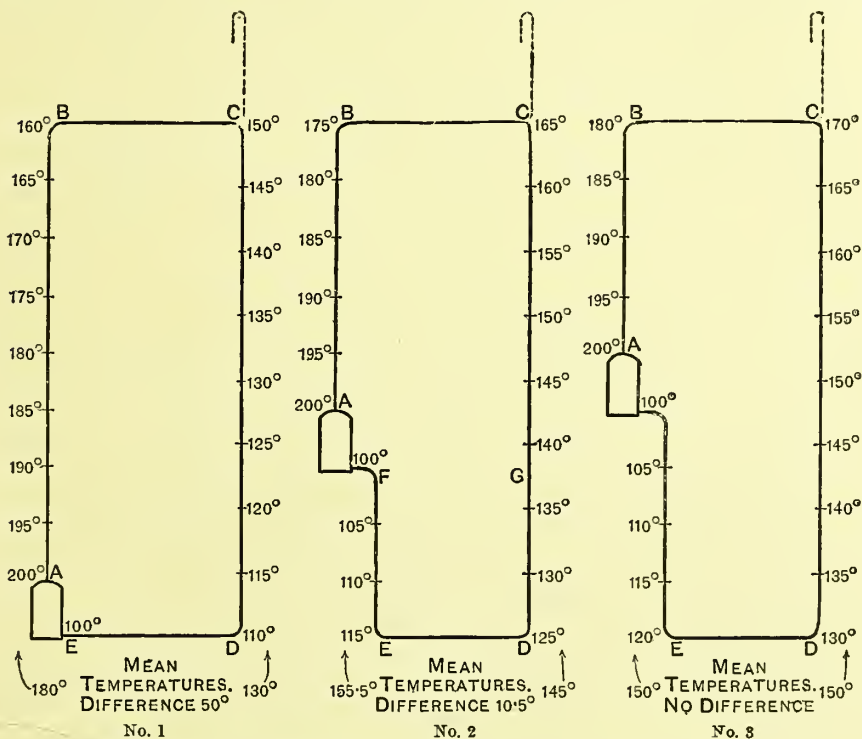


Fig. 825.—Effect on Mean Temperatures in Flow and Return Pipes when Return Pipes are dipped below the Boiler

an apparatus similar to No. 2, but the velocity will be slow owing to the small difference in weight between the ascending and descending columns of water and the reduced circulating head. In No. 2 the mean temperatures of the two columns are 155.5° and 145° respectively, thus giving a difference of 10.5° F., while in No. 1 a difference of 50° is shown between the two columns.

No. 3 shows the boiler fixed at a point midway between B and E; the mean temperatures of the up and down columns are shown to be the same, and therefore it would appear that no circulation would take place. Such a thing is possible, providing the pipes are arranged as shown in No. 3; but in ordinary heating systems the horizontal pipe BC would be much longer than shown, and consequently the results would be modified. The

actual depth that water can be made to circulate below the boiler in an ordinary heating system will depend largely upon the distance of the dip from the boiler, the arrangement of the pipes, and the rate at which the pipes cool.

Fig. 826 indicates what effect the arrangement of long horizontal pipes has upon the rate of circulation when the head and lengths of pipes are the same in each case. Horizontal pipes have no direct influence upon the motive power, their chief effect being to cool the water as it passes through them, and to retard the circulation. The motive power producing circulation is only calculated from the vertical height.

In fig. 826 the pipes are 4 in. in internal diameter, and are supposed to be cooled half a degree for each foot run. It will be observed that the

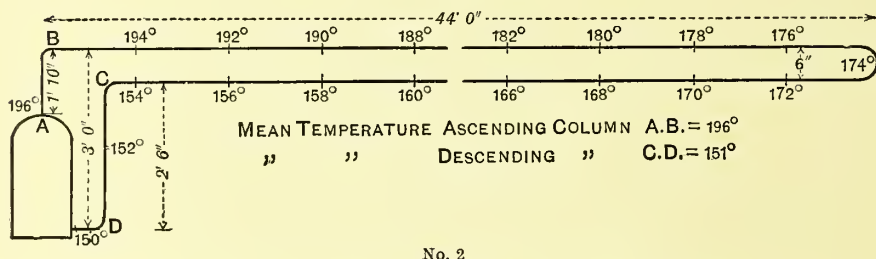
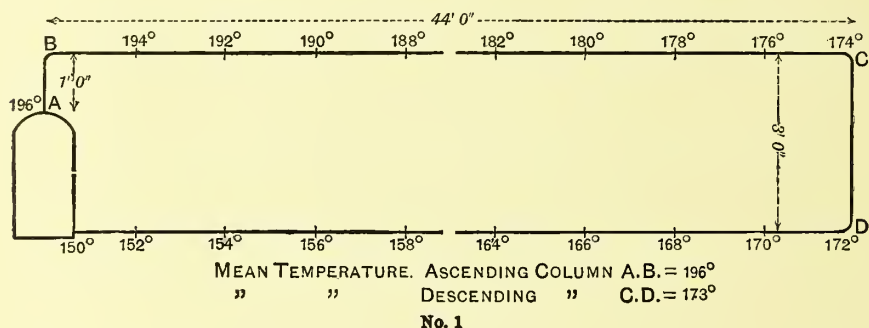


Fig. 826.—Effects on Mean Temperatures of Different Arrangements of Pipes

average temperature of the ascending column AB (No. 1) is 196° F., and of the descending column CD 173° F., the difference in temperature between the two being 23° F. In No. 2 the average temperatures of the up and down columns are 196° and 151° F. respectively, thus giving a difference of 45° F. The power producing circulation is greater in No. 2 than in No. 1, owing to the water in the horizontal pipes of the latter arrangement cooling more before descending to the boiler.

The system illustrated in No. 1, fig. 827, has its return pipe dipped at a point distant from the boiler, in order to cross a passage or doorway; the return is fixed 1 ft. below the flow pipe. The chief resistance to a free circulation in this case is the denser column of water EF, which has to be displaced in an upward direction. In No. 2 the return pipe crosses a passage near the boiler, and is fixed 2 ft. below the flow pipe further

to reduce the motive power. The horizontal return would be better if fixed close to the flow pipe. A horizontal flow pipe should not be dipped or trapped; but where it is necessary to pass some obstacle, this pipe must rise and cross it and fall again on the opposite side.

The following calculations will show how to find approximately the motive power available in Nos. 1 and 2, fig. 827, and also the extent to which pipes can be safely dipped.

The area of a pipe 4 in. in diameter equals 12.5664 sq. in.; therefore the volume of water in 1 ft. of 4-in. pipe = $12.5664 \times 12 = 150.7968$ or (say)

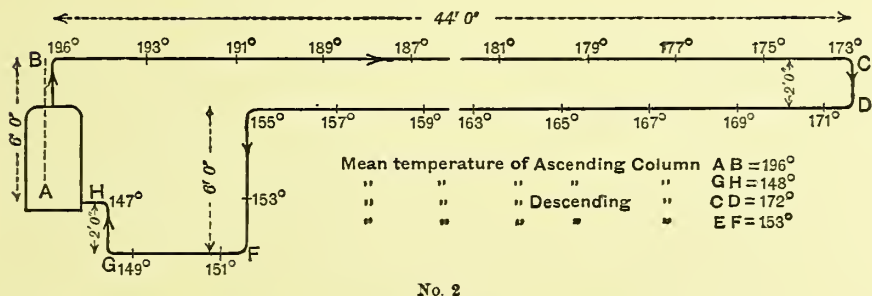
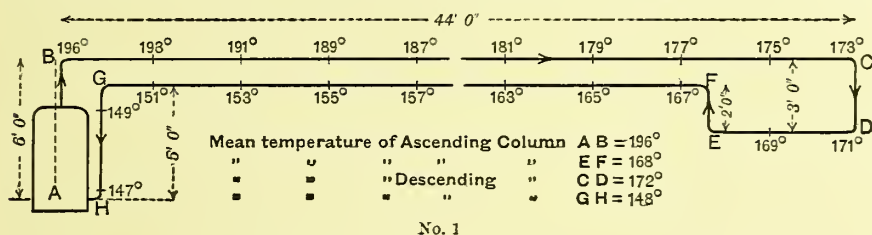


Fig. 827.—Effects on Mean Temperature of Dips at different Points in Return Pipes

150.8 cu. in. From Table III the weight in grains of 1 cu. in. of water at different temperatures can be taken and converted into lb.

Weight of a column of water 4 in. in diameter and 1 ft. in height at—

142° F.	=	150·8	×	·03549	=	5·35	lb.
148° F.	=	150·8	×	·03543	=	5·342	„
153° F.	=	150·8	×	·03537	=	5·334	„
168° F.	=	150·8	×	·03519	=	5·305	„
172° F.	=	150·8	×	·03514	=	5·297	„
196° F.	=	150·8	×	·03482	=	5·25	„

In No. 1, fig. 827, the Ascending column A B weighs $5.25 \times 6 = 31.50$ lb.

Ascending column EF weighs $5.305 \times 2 = 10.61$ „

Total weight of ascending columns = 42.11 „

Descending column CD weighs $5.297 \times 3 = 15.891$ lb.

Descending column GH weighs $5.342 \times 5 = 26.710$ „

Total weight of descending columns = $\overline{42.601}$.

$\therefore$ Motive power in No. 1, fig. 827 = $42.601 - 42.11 = .491$, or nearly $\frac{1}{2}$ lb.

In No. 2, fig. 827, the Ascending column A B weighs	5·25	×	6	=	31·5	lb.
Ascending column G H weighs	5·342	×	2	=	10·684	„
Total weight of ascending columns				=	<u>42·184</u>	„
Descending column C D weighs	5·297	×	2	=	10·594	lb.
Descending column E F weighs	5·334	×	6	=	32·004	„
Total weight of descending columns				=	<u>42·598</u>	„

∴ Motive power in No. 2, fig. 827 = 42·598 - 42·184 = 414 lb.

The calculations show that systems similarly arranged would work satisfactorily.

CHAPTER III

PIPES AND FITTINGS

Heat-emitting surfaces take the form of straight pipes, coils, and radiators. For greenhouse work 4-in. pipes are largely used, as they hold a large volume of water and allow a steady heat to be maintained. Pipes are seldom used alone in dwelling houses, offices, &c., where the heating apparatus is either low-pressure hot water or low-pressure steam. For warming factories, &c., pipes are chiefly used, as coils and radiators cannot always be conveniently placed.

Wrought-iron pipes may be either galvanized or plain, and are chiefly used for mains and branches 2 in. or less in diameter. These pipes are strong, and connections can be readily made between them and radiators. They are also made in long lengths, easily jointed and bent to suit various positions, easy to fix, and neat in appearance.

Cast-iron pipes are generally used for mains 3 in. and upwards in diameter, and are cheaper than wrought-iron pipes. They are better suited for horticultural work, and for fixing in channels or damp positions, as they are not so readily corroded.

Copper pipes are used for high-class work in private houses, hospitals, and public buildings. Small mains and branches are often of copper, while the large mains are usually of iron. Copper pipes should be stout enough to take the ordinary threads, as lighter pipes are not satisfactory unless special joints are used. The joints of thin copper pipes are usually screwed with a fine thread, and also sweated to the fittings with soft solder. These joints, however, are sooner or later destroyed by the unequal expansion and contraction of the metals, and in some cases also by galvanic action. The fittings used in connection with copper pipes are made either of brass or gun metal, the latter being the more durable.

It is a common practice to solder the joints of strong copper pipes, but trustworthy joints can be made by using strong gun-metal fittings, with male and female ends well tapered, and screwed with the ordinary

coarse thread, and put together with red and white lead or other suitable mixture. The joints of light copper pipes may be brazed, but if the water in the pipes is of an acid character there is danger of an electrolytic action being set up, and the joints eventually destroyed or rendered defective, although much more slowly than when soft solder has been used. The most satisfactory method at present in use for uniting light copper pipes is the compression joint, but special fittings are required.

Copper pipes may be bent in the following way.¹ If the copper is hard, soften the part where the bend is required by heating to dull redness, and allowing it to cool gradually. If the pipe to be bent is over $\frac{1}{2}$ in. in diameter, it can now be loaded with either sand, resin, pitch, or lead. When only a few bends require to be made, a hole can be bored into a plank, and the sharp edges well rounded off. The loaded pipe is slipped through the hole to the point where the bend is required, and the pipe pulled gently round; if the bend is carefully turned, the pipe will only flatten slightly, and this can be rounded into shape (while the pipe is still charged) with either a round-faced hammer or the back of a hardwood dresser. Sand is very suitable and convenient for making slow bends, but the ends of the pipes must be well plugged to prevent the sand running out while bending. Resin can be used for quick bends; this is also a convenient material, as the pipes only require to be loaded in the length where the bend is required, and resin is easily melted out after a bend is made. Lead is more troublesome to use than resin. Pipes $\frac{1}{2}$ in. in diameter and less can often be bent without loading.

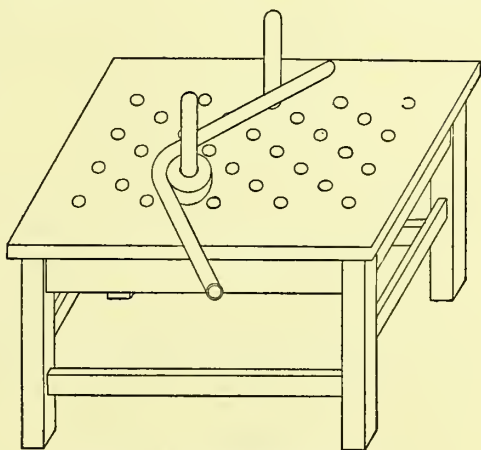


Fig. 828.—Method of Bending Copper Pipes

A better mode of bending pipes, where a large number of bends are required, and where a bending machine is not available, is to fix a grooved pulley on to an iron frame. A convenient type of frame (fig. 828) is one fitted with holes, into which two strong pins can be fixed to suit the bend required. On one of the steel pins the pulley turns, while the other holds the pipe during the process of bending.

Pipe Joints.—The joints for wrought-iron and copper pipes are chiefly of the screwed class, while those for cast-iron pipes are generally of the spigot-and-socket or flange type.

The *spigot-and-socket joint* (fig. 829) can be made in various ways. For hot-water apparatus, a common method of jointing is to place the socket and spigot ends in position, insert a few rings of tarred rope yarn, and fill the remaining space with rust cement, the whole being well staved up.

¹ See also Vol. I., p. 89.

Quick-setting rust cement is not to be recommended, as the expansion is greater than with slow-setting cement, and the sockets are liable to be fractured.

A good method of making spigot-and-socket joints is first to insert a few rings of spun-rope yarn, well covered with a mixture of red and white lead, which has been worked into the fibres; after this is in position, two

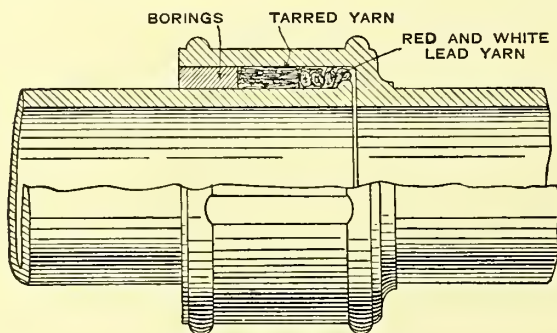


Fig. 829.—Spigot-and-socket Joint

or three rings of tarred yarn can be inserted, and the remaining space (about $\frac{3}{4}$ in.) filled up with rust cement. The rust cement is occasionally omitted, the joints being made partly as before described; but the remaining space is filled with a mixture of red and white lead and chopped hemp. This mixture has a little gold size added to facilitate setting.

These joints are also sometimes made by first inserting about three rings of red- and white-leaded yarns, the remaining space being filled solid with good Portland cement.

Flange connections (fig. 830) make very strong joints, but are clumsy in appearance; and as the flanges are cast on the pipes, the connecting pieces must be made to exact lengths. Flange joints are suitable for large pipes in basements and similar places. These joints are made tight by inserting a suitable packing material between the flanges, which are held together by a number of bolts and nuts. A great difficulty has been experienced in making flange joints stand for any great length of time on pipes which convey superheated steam, the packing material being the chief source of trouble.

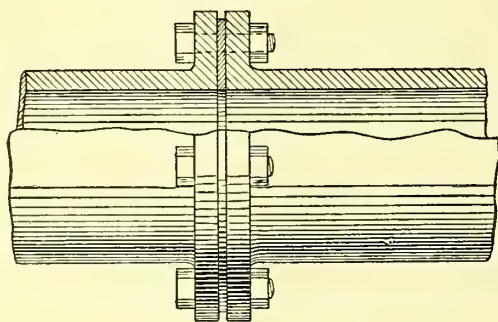


Fig. 830.—Flanged Joint

The materials commonly used for the packings of flange joints are india-rubber, asbestos, metallic lead, and corrugated metal rings. India-rubber and asbestos rings are satisfactory for low-pressure hot water, but high-pressure steam destroys both these materials. Asbestos packings are suitable for low-pressure steam. Metallic lead rings are satisfactory when the flanges have been truly faced. Corrugated metal rings make good joints for high-pressure steam. These rings are usually made of brass, and both sides are smeared with red and white lead; the flanges are painted, and the whole bolted together. As a portion of the material is confined in the grooves, a substantial joint is made.

Expansion of Pipes.—When long stretches of pipes are rigidly fixed, a breakage of one or more joints or of the pipes themselves is almost sure to take place. Steam pipes require more care in fixing than hot-water pipes, as the former are very quickly heated and cooled, which causes them to expand and contract at a more rapid rate.

The following short table gives the linear coefficients of expansion for different metals, the units of length and temperature being 1 ft. and 1° F. respectively:—

Brass	=	·000011		Cast iron	=	·0000063
Copper	=	·00001		Wrought iron	=	·0000073

Example.—If a wrought-iron pipe 200 feet long at 32° F. is heated to 212° F., what will be its increase in length?

$$\begin{aligned}\text{Increased length} &= 200 \times (212 - 32) \times \cdot 0000073. \\ \text{,,} \quad \text{,,} &= \cdot 2628 \text{ foot} = 3\cdot 15 \text{ in.}\end{aligned}$$

Bends in pipes are good for allowing movement of the pipes to take place; and where they are absent or insufficient, movement must be provided for by fixing *expansion bends* or joints in the line of pipes.

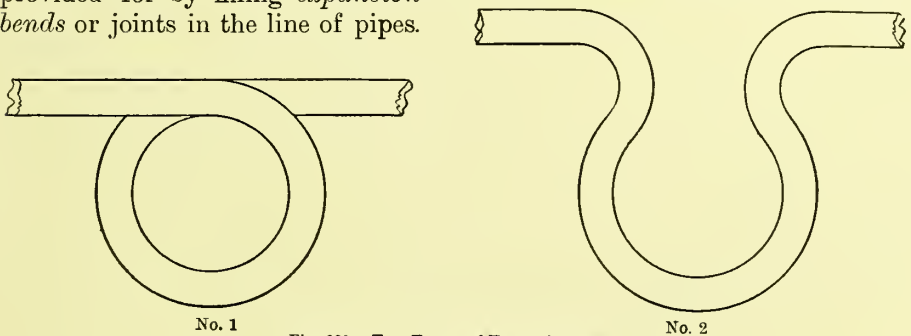


Fig. 831.—Two Forms of Expansion Bend

Fig. 831 illustrates two forms of expansion bends which are often used. Wrought-iron expansion bends are really too rigid, and often break at the joints. Copper bends are the most satisfactory for general heating work, as they readily yield either backwards or forwards without unduly straining the joints. To avoid excessive strain on the pipes and fittings, the various connections and branches must not be too rigidly fixed. When expansion bends are necessary on horizontal pipes, they must be fixed horizontally, so as to avoid trapping the pipes. The most suitable place for expansion bends or joints is midway between rigid points.

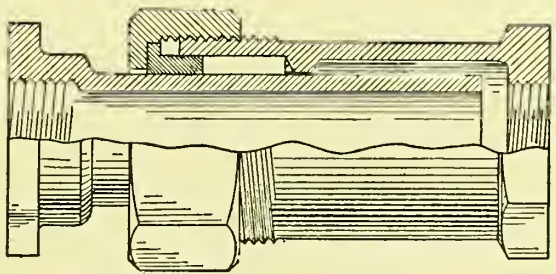


Fig. 832.—Expansion Joint

Expansion joints are not so good as copper bends, as they require more

attention and are liable to leak at the stuffing-box. A common form of expansion joint (fig. 832) simply consists of one tube sliding inside another, the joint being kept water-tight by the packing material in the stuffing-box.

For low-pressure hot-water pipes expansion joints are largely used, especially in connection with cast-iron pipes. Fig. 833 shows Jones's

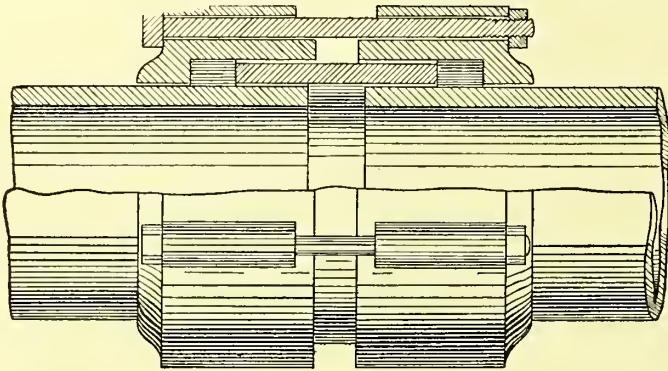


Fig. 833.—Jones's Expansion Joint

expansion joint, which possesses several important features. It consists of two loose collars, two rubber rings, one iron ring, and two bolts and nuts, and is made water-tight by compressing the rubber rings between the iron ring and loose collars. As it is applied to plain pipe ends, this joint is convenient for effecting repairs, and is easily made; but it is only suitable for low heads of water—about 20 feet and under.

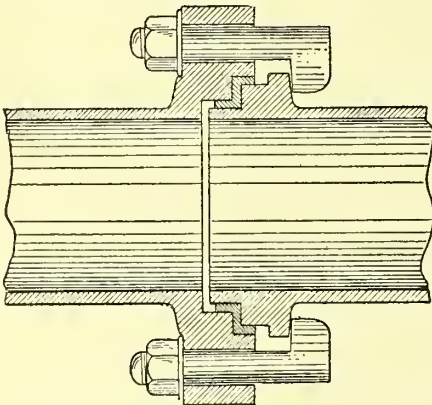


Fig. 834.—Richardson's Expansion Joint

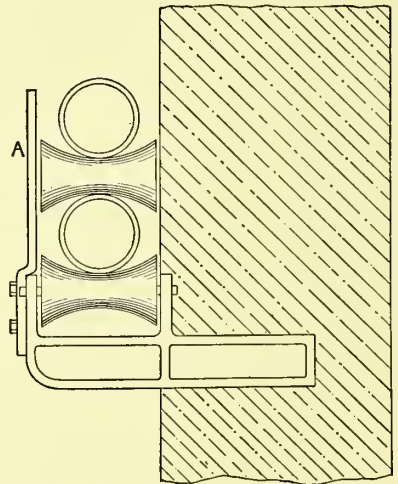
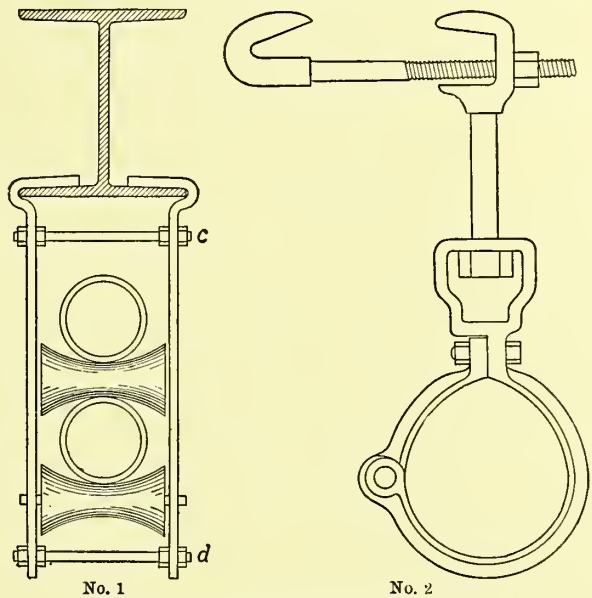


Fig. 835.—Bracket supporting Pipes

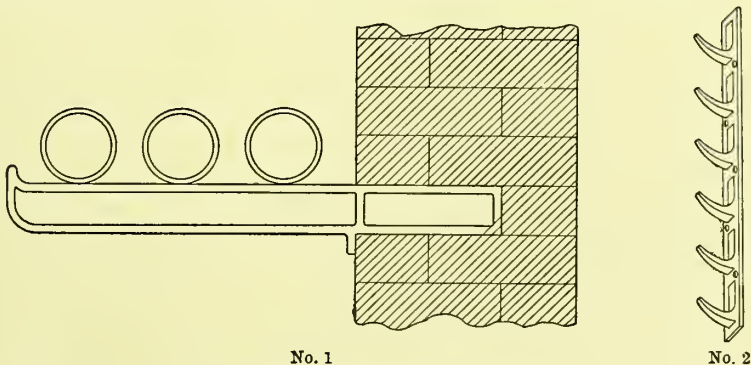
Richardson's patent expansion joint (fig. 834) is suitable for greater pressures. The ends of the pipes in this case are specially formed, a rubber washer is fixed between the two surfaces, and the joint secured by bolts and nuts. When a pipe requires to be shortened, the socket end is cut off, and a special flange is fixed on to the pipe to form the socket required.

Fixing Pipes.—In large buildings it is usual to fix the main horizontal pipes in basements, passages, or subways; occasionally the subways serve the purpose of fresh-air ducts as well. There are numerous ways of fixing or supporting pipes, but the method adopted depends largely upon the size of the pipes and the kind of material to which the pipe-hangers or supports can be fixed. Fig. 835 illustrates how two pipes, one above the other, can be supported so that movement can easily take place. The wall bracket is of cast iron, with the bottom roller attached, whilst the upper roller may be loose (although better if fixed), and the pipes are kept in position by the stay bar (A). Where pipes must be fixed to a steel girder an arrangement similar to No. 1, fig. 836, can be used; the sides of the hanger are firmly held in position by the bolts c and d. Another method of securing single pipes to steel girders is by means of a swivel hanger (No. 2, fig. 836).

For short horizontal pipes rollers are not necessary, and plain brackets or hangers may be used. A simple arrangement is indicated in No. 1,



No. 1
No. 2
Fig. 836.—Hangers supporting Pipes under Steel Joist



No. 1
No. 2
Fig. 837.—Brackets for supporting Pipes

fig. 837; it is suitable for supporting two or more pipes, and affords facilities for taking off the branches at different points. No. 2 illustrates a wall bracket for supporting a number of pipes fixed horizontally one above the other.

Malleable-iron pipe-hangers can be used for different sizes of pipes which are fixed near ceilings. A hanger suitable for screwing to woodwork is shown in fig. 838. For fixing vertical iron or copper pipes to a wall or to woodwork, brackets similar to Nos. 1 and 2, fig. 839, can be used. Pipe brackets often require to be designed to suit special circumstances.

When vertical pipes pass through floors and ceilings, **flange and ceiling plates** can be used to cover up the spaces around the pipes; to make a neat finish adjustable plates can be obtained, and fixed after the pipes are in position.

Pitch of Pipes.—Hot-water pipes should have a pitch of 1 in. in 10 ft. where possible. When pipes are fixed perfectly level, the circulation in ordinary systems is greatly impeded, especially where small pipes are used. The circulation is always quick in vertical pipes, and this accounts mainly for the higher parts of buildings being more thoroughly heated than the lower.

In order to obtain an approximately equal degree of heat throughout a system, not only do the pipes require to be correctly sized, but the mode of making the **branch connections** also requires consideration. A good plan is to arrange the branches so that circulation will be accelerated in the lowest circuits. Fig. 840 illustrates how the connections with a branched circuit can be made to give good results. The mode of connecting with

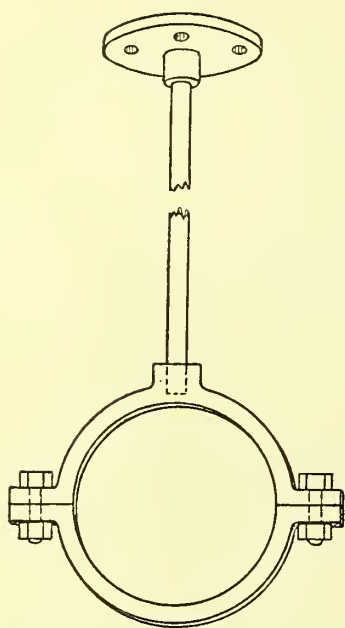


Fig. 838.—Pipe-hanger

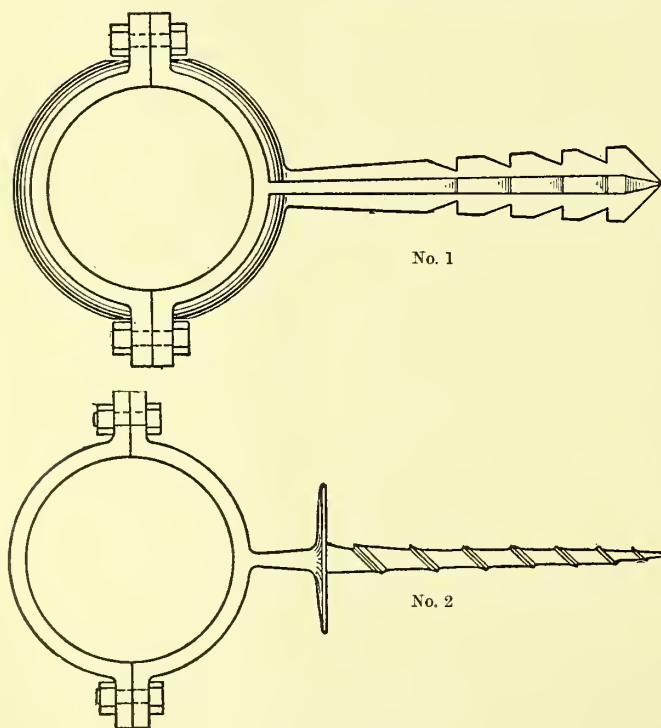


Fig. 839.—Pipe Hooks or Brackets

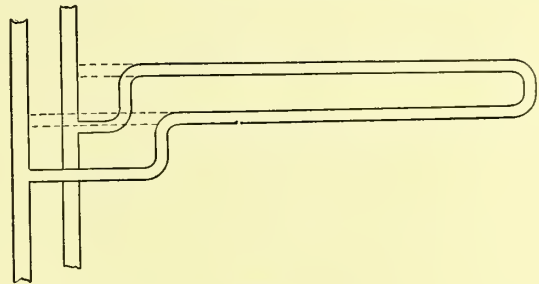
the vertical pipes shown in No. 1 is far better than making straight connections as shown by dotted lines, both as regards the heating of the circuit and allowing a little freedom for the pipes to expand and contract. Another arrangement is shown in No. 2.

Special fittings can be obtained for small pipes such as risers to radiators; they are very convenient, and occupy less space and are neater than ordinary fittings. The special connection No. 1, fig. 841, aids in equalizing the temperature of the water in radiators on different floors. The inlet is denoted by A, radiator connection by B, and the riser to upper floor by C. A fitting like No. 2, fig. 841, may be used on horizontal pipes when it is desired to favour

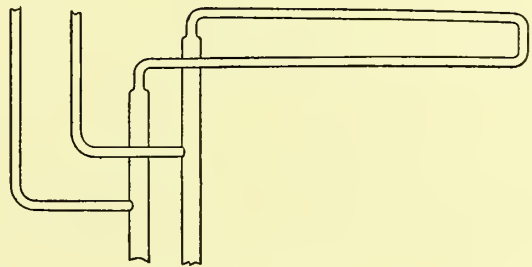
the circulation in the branch; the lip A divides the flow, one portion of the heated water passing to B and the other to C. The free use of fittings like this would no doubt be detrimental to the circulation if the horizontal pipes were long, as each lip forms a decided obstruction. A curved tee (No. 2, fig. 842) would in most cases be preferable. Fig. 842 shows two useful tees for minimizing friction. The ordinary right-angle tees are satisfactory if well arranged, and are cheaper than special fittings.

When a number of connections are taken from a horizontal main, the water will circulate most freely through those which offer the

least resistance. Sometimes stop cocks are fixed on the branches to regulate the flow of water through them, but in many cases it is sufficient to fix the tees on the horizontal mains in such a manner as to retard the

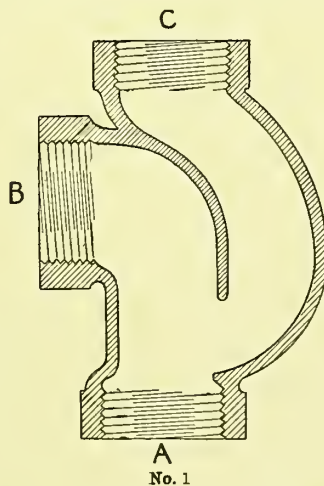


No. 1

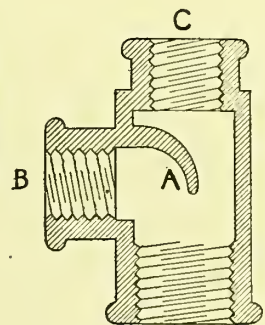


No. 2

Fig. 840.—Connections of Branch Circuits



No. 1



No. 2

Fig. 841.—Special Connections for Branches

circulation through one branch and to accelerate it in another. A horizontal main, to which two risers, A and B, are joined, is shown in fig. 843. Supposing that they are some distance apart, that both connections are made in the same way, and that the lengths and diameters of the branches are the same, then the greater part of the hottest water will circulate

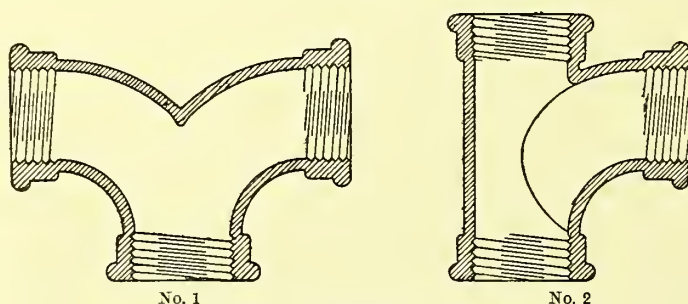


Fig. 842.—Two Forms of Tee

through A, the direction of the flow being from A to B. But if the risers are arranged as shown, the circulation through branch A would be impeded, owing to its being connected with the side of the main and to the short horizontal branch pipe, while the circulation would be aided through B by taking the branch directly from the top of the pipe.

The main pipe from a boiler should not immediately rise to a high point before a double bend

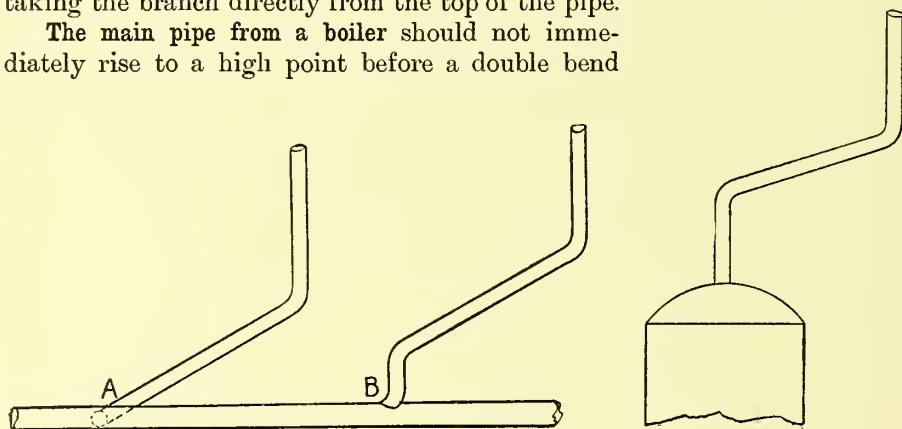


Fig. 843.—Two Methods of Connecting Flow Branches

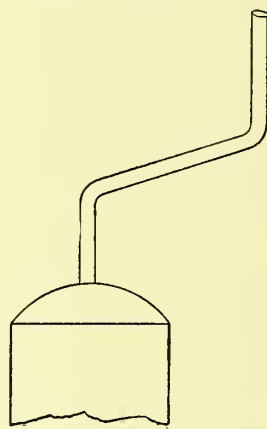


Fig. 844.—Bends above Boiler

has been made in it similar to that shown in fig. 844. Such a bend allows the pipes a little freedom to move without straining the joints. Where risers are taken from a main, or where radiators are connected up, the pipes should be treated in a similar way.

CHAPTER IV

HEATING SURFACES: COILS AND RADIATORS

When a large amount of heating surface requires to be concentrated in a small space, a coil or a radiator is necessary. The distinction between a coil and a radiator is not always very clear, but, generally speaking, coils are chiefly composed of horizontal heating surfaces, whilst radiators, with a few exceptions, have the greater part of their surfaces vertical. A coil may take various forms, and may be composed of a number of separate parts or be simply a wrought-iron pipe which has been bent into different shapes.

A box coil is illustrated in fig. 845, and consists of two vertical box ends, into which the horizontal pipes are

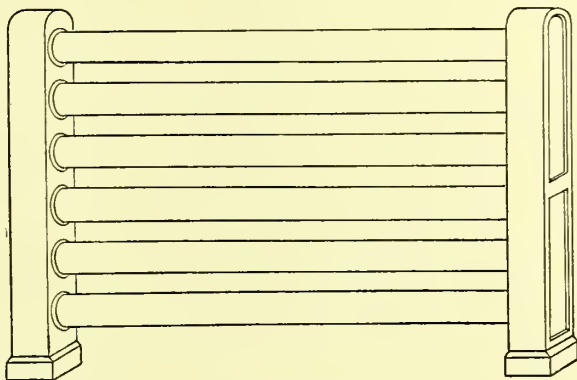


Fig. 845.—Box Coil

joined. The box ends are cast to receive either single or double rows of pipes, and the coils can be easily built up on the job for which they are required. They form very efficient heating surfaces, and are cheap and easily fixed.

Coils were used long before the advent of the radiator, and, as they do not usually possess an elegant appearance, they are often covered with ornamental cases; but these greatly impair the heating efficiency of the coils and form receptacles for the accumulation of dust.

For indirect heating surfaces, simple wrought-iron coils (fig. 846) are largely used, the air being admitted between the pipes. A gridiron coil (fig. 847) may be used for heating factories, where the

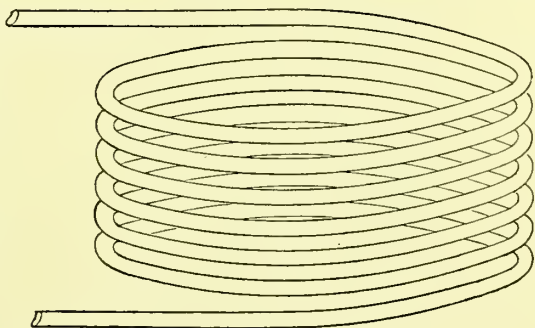


Fig. 846.—Wrought-iron Coil

floor space is occupied by machinery, and where for other reasons the heating surfaces cannot well be fixed on the floor. These coils are suspended from the ceilings in any convenient and suitable positions, and are suitable for either hot water or steam.

Most of the modern radiators are built up in sections, for either low-

pressure steam or hot-water heating. Radiators that are specially made for steam have their sections joined together at the bottom only. In hot-water radiators it is essential that the sections communicate with each other both at the bottom and top, in order that the water may circulate freely through the sections, and that the air may escape at one common outlet. These radiators are also used for steam.

Radiators are made in numerous plain and ornamental shapes, and are

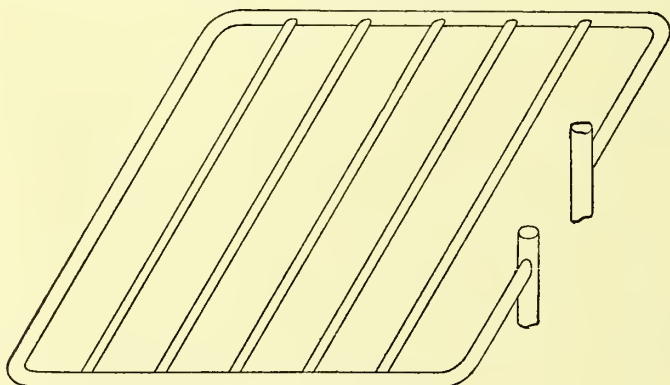


Fig. 847.—Gridiron Coil

suitable for warming almost every kind of building. The advantages possessed by radiators over coils are that more heating surface can be placed in a limited space, and that they are neater in appearance and collect less dust.

The sections of radiators may be joined by means of **push or screwed nipples**. The push nipples (fig. 848, No. 1) are tapered and truly faced, and the openings in the sections are coned to receive them, so that when joined a good connection is made. To bind the section together wrought-iron tie

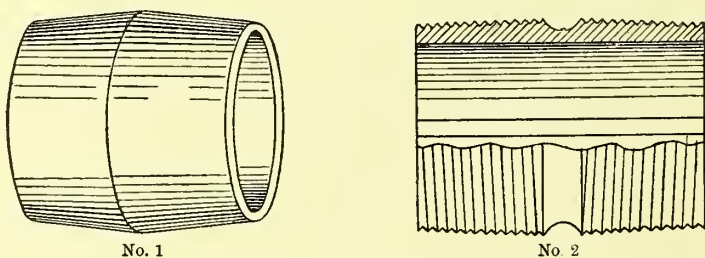


Fig. 848.—Nipples. No. 1, Push; No. 2, Screwed

rods are required. The other nipple (No. 2) is screwed with left- and right-hand threads, the sections being tapped accordingly to receive them. These nipples make strong and durable connections, and are superior to the push nipples in most respects. When screwed nipples are used tie rods are not required, and sections can be added or taken off a radiator without disturbing the joints of the remaining sections. These nipples have small lugs formed on their inner surfaces to afford a hold for a keyed rod in order to turn them.

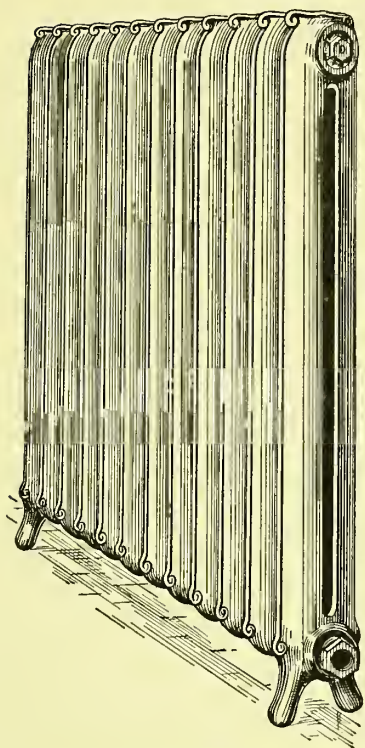


Fig. 849.—Single-column Radiator

Loop radiators are the most efficient types for direct heating work; they are made in various heights, and each section may have one to four columns in its width. The “Duchess” single-column radiator, made by the Beeston Foundry Company, is shown in fig.

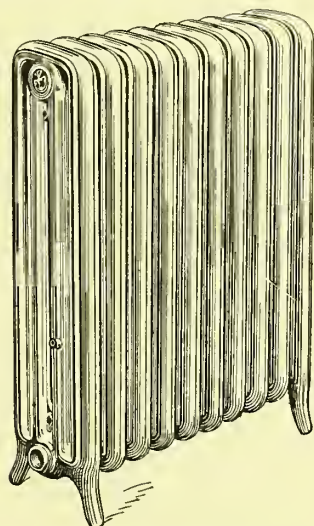


Fig. 850.—Four-column Radiator

849. Each section, 36 in. in height, contains $3\frac{1}{4}$ sq. ft. of heating surface and for 30 in. in height $2\frac{1}{2}$ sq. ft. of surface. Fig. 850 gives the “Peerless”

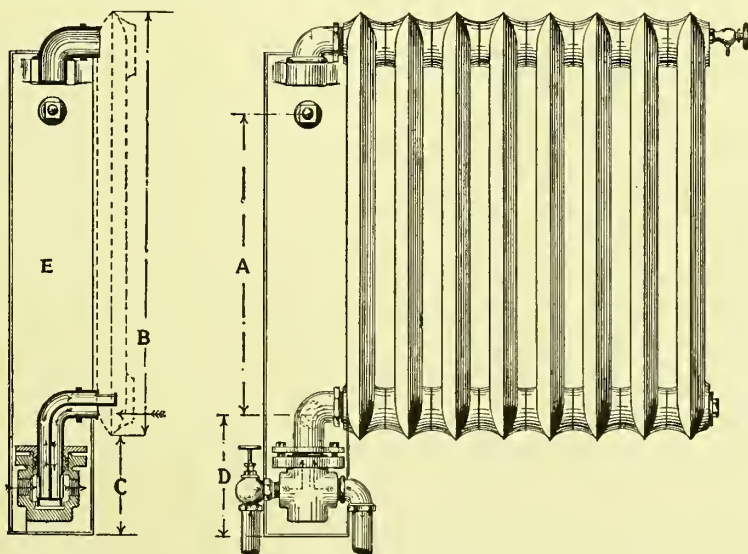


Fig. 851.—Swing Radiator

four-column radiator, made by the National Radiator Company; each section contains 8 sq. ft. of heating surface.

For hospital work radiators are used with their columns a little farther apart than those already shown, in order that they may be more easily cleansed. Fig. 851 shows the "Astro" swinging radiator, which is suitable for fixing in front of a fresh-air inlet to warm the incoming air. The hinged fittings on the radiator allow it to swing outwards, so that free access can be obtained to the air duct for cleaning it. The supply and return connections are made in the combination socket and stuffing-box, and a web up

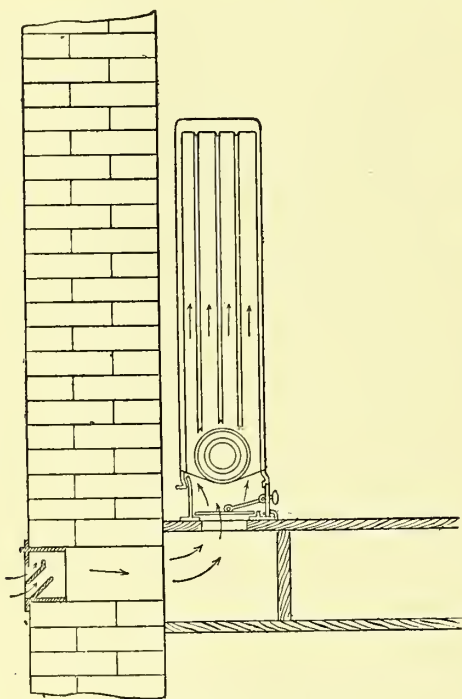


Fig. 852.—Ventilating Radiator

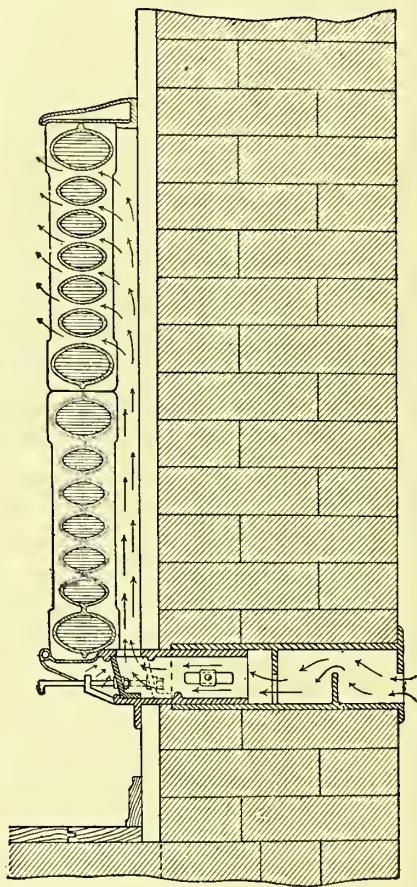


Fig. 853.—Ventilating Radiator fixed to Wall

the centre divides the up and down currents. The common hospital class of radiator is similar to fig. 851, but fixed on plain feet.

Special radiators can be obtained for fixing in various positions, such as around columns, for the corners of passages, and in halls and staircases; some of these can be procured with marble tops. Dining-room radiators, provided with hot closets or chambers, can also be obtained.

Ventilating radiators, sometimes termed direct-indirect radiators, are fixed in connection with fresh-air inlets. An example is shown by fig. 852, where the fresh-air conduit is brought through the floor. The amount of fresh air which passes through the duct can be regulated by a damper fixed

at the bottom of the radiator. To prevent the discoloration of walls by heated particles of dust, it is a good plan to fix on the top of the radiators light shields which will divert the heated air towards the centre of the apartment, or to fix the radiators, where circumstances will permit, 4 to 6 in. from the walls.

In buildings where direct or direct-indirect heating is required, and ordinary radiators cannot easily be used, wall radiators can be adopted. These radiators can be fixed on a wall near the floor or ceiling, or at any other point desired. A section of Fowler & Wolfe's wall radiator, fixed in position, is illustrated in fig. 853. The radiator is supported on iron brackets in front of a fresh-air inlet. The baffle plates in the fresh-air inlet are provided to break the force of strong currents of air. The air supply can be regulated as desired by operating the damper at the bottom of the radiator. When the damper is drawn outwards, air is admitted from the outside; when pushed inwards, the outside air is shut off, and air is only admitted behind the radiator from the room. The damper can also be arranged to admit the passage of air behind the radiator, both from the outside and from the room. The openings of the lower series of sections are closed by a web, so that the air is only discharged into the apartment from the upper half of the radiator. The air escapes in a horizontal direction, so that any impurities are deflected away from the wall.

A plain vertical-column wall radiator (fig. 854) is very suitable for hospitals and other institutions, as the space underneath can be readily cleaned; it is also useful where the hot-water pipes run across the floor of a room, as the radiator can be fixed conveniently over them.

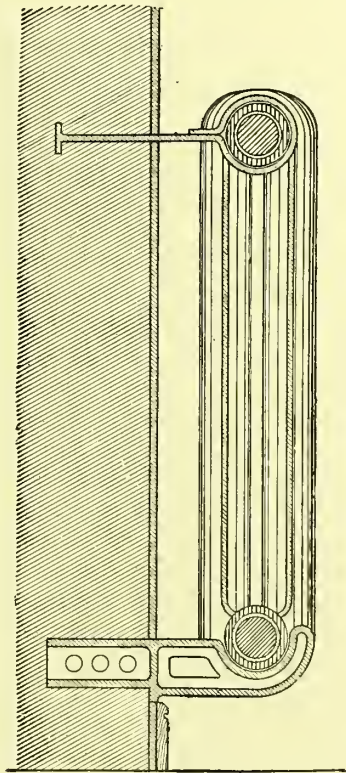


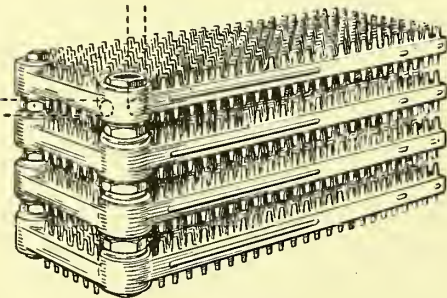
Fig. 854.—Radiator supported on Brackets

Indirect radiators used in connection with systems of ventilation are made in a variety of forms. The principal object aimed at is to mass a large amount of effective heating surface into a small space for as small a sum as possible, while at the same time the flow of air between the heating surfaces is not unduly retarded. Wrought-iron pipes, 1 in. in diameter, coiled and fixed close together (fig. 846), are largely used for the purpose. With indirect heating, the air is heated by being propelled or drawn over heated surfaces and through special air ducts, from which it is discharged through registers into the apartments to be warmed.

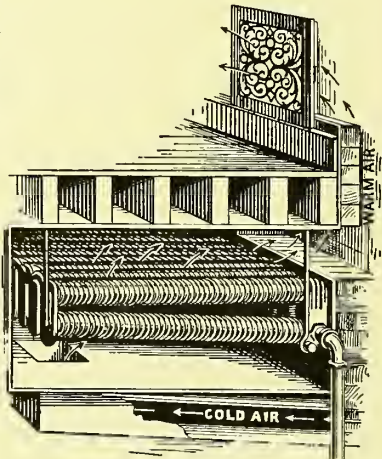
A number of indirect heating surfaces massed together are often termed a *battery*. No. 1, Fig. 855, illustrates a cast-iron indirect radiator with extended surfaces; each section is rated as containing 20 sq. ft. of heating

surface. Another pattern (No. 2) is fixed in a compartment with fresh-air inlet and outlet as shown.

Before the fresh air for a simple system of ventilation is delivered into a building, the suspended matter which it contains should be eliminated as far as possible by intercepting it with a fine wire-gauze screen. Wire gauze is very useful when fixed in front of the fresh-air inlet



No. 1



No. 2

Figs. 855.—Radiators for Indirect Heating

of a ventilating radiator, as it also serves to break the force of the wind when this is blowing directly into the inlet.

Table IV gives the sizes of branches and connections to radiators.

TABLE IV

HOT-WATER RADIATORS

Less than 40 sq. ft. of radiation, 1 in. diameter.			
More than 40	„	„	and less than 75, 1¼ in. diameter.
75	„	„	and over, 1½ in. diameter.

STEAM RADIATORS

One-pipe Work.		Two-pipe Work.		
Radiation.	Diameter.	Radiation.	Diameter.	
Less than 24 sq. ft.	1 in.	Less than 48 sq. ft.	Supply. 1 in.	Return. ¾ in.
24 sq. ft. and less than 60 ...	1¼ „	48 sq. ft. and less than 90 ...	1¼ „	1 „
60 sq. ft. and less than 100 ...	1½ „	90 sq. ft. and over...	1½ „	1¼ „
100 and over ...	2 „			

The sizes of branches given above apply to ordinary systems; if the horizontal branches between the supply pipes and radiators are rather long, the branches should be increased by one size.

Measurement of Heating Surfaces.—In finding the superficial area of heating surfaces, the external surfaces are measured, and not those in contact with the water or steam.

There is no direct method of computing the areas of radiators. The area of one section could be found by dividing it up into a number of parts, and calculating each part separately, and afterwards adding together. When the area of one section is known, the total area, of course, is found by multiplying it by the number of sections in the radiator.

To find the area of the heating surfaces of pipes, *multiply the length of the pipes in feet by their circumference—also in feet.*

The circumference is found by multiplying the diameter by $\frac{22}{7}$.

Therefore $a = \frac{d}{12} \times \frac{22}{7} \times l$ (6)

Where a = area of surface in square feet.

„ d = external diameter of pipe in inches.

„ l = length of pipe in feet.

Effects of Different Forms of Heating Surface.—Small pipes emit more heat per unit area of surface than large pipes, provided the temperatures of the water or steam under the surfaces and the rate of circulation are the same in each case. When pipes are grouped together, less heat is emitted per unit area of surface than with single pipes, as a portion of the radiant heat is not projected into the apartment, but is simply radiated and re-radiated between the heating surfaces. The efficiency of heating surfaces is also affected by their height, for the air currents, upon being warmed by contact with the lower surfaces, absorb less heat as they ascend. Radiators and coils which have their surfaces very close together are not so efficient as those which have their surfaces fixed farther apart. The amount of heat emitted also depends upon the nature of the surface: 1 sq. ft. of ornamental surface is not equivalent to 1 sq. ft. of plain surface. The most efficient radiators are the single-loop or column class, and as the columns in each section are increased in number, their heating values per unit area of surface will decrease.

In combined heating and ventilating systems it is a common practice for the heating to be done on the indirect method. Indirect heating has both its drawbacks and advantages. Its chief merits are that the heating surfaces are out of sight, and that, when mechanical ventilation is adopted, the heating surfaces can be concentrated in the basement of the building. Its disadvantages are: (1) the value of the radiant heat is lost; (2) the air is not so agreeable as that warmed by radiant heat; (3) it is sometimes more costly, as a greater amount of heating surface is necessary to warm the air than with direct heating. This last condition is largely controlled by the size and character of the building, for if mechanical ventilation is necessary, and the fresh air is either propelled or drawn over the heated surfaces, they will emit much more heat than when standing in nearly still air.

For buildings where fans are not required, ventilating radiators are

very suitable for combined heating and ventilation. Plain loop radiators, which admit of their surfaces being more readily cleaned, can also be utilized, by arranging a conduit to deliver fresh air beneath them.

CHAPTER V

CALCULATION OF HEATING SURFACES

Losses of Heat from Buildings.—Various rules or formulæ are given by different authorities for finding the necessary amount of heating surface for warming buildings. A common rule is that which allows a given number of square feet of heat-emitting surface for every 1000 cu. ft. of space. Although this is convenient for approximations, it does not take into consideration the varying conditions that are met with in buildings.

A better rule to adopt is one that considers separately the different channels through which heat is lost. When heat is emitted from radiating surfaces, one portion is utilized in warming the air of the building; a second portion is transmitted through external walls; a third through windows; and the remaining portion is absorbed or lost through internal walls, floors, ceilings, doors, and crevices.

The amount of heat transmitted through walls becomes less as their thicknesses are increased.

Tables V and VI have been taken from the German work by Recknagel and Rietschel, and converted into English units by Prof. Kinealy, and are given in his work *Formulas and Tables for Heating*.

TABLE V.—LOSS OF HEAT THROUGH BRICK WALLS IN BRITISH THERMAL UNITS PER SQUARE FOOT OF SURFACE PER HOUR, PER DEGREE DIFFERENCE OF TEMPERATURE, THE BRICKS BEING $8\frac{1}{4} \times 4 \times 2$ IN., WITH $\frac{3}{8}$ IN. MORTAR JOINTS

Thickness of Wall.	Outside Walls.		Inside Wall. Both Sides Plastered.	With Additional Stone Face.			With Air Space of 2.4 in. Plastered.
	No Plaster.	One Side Plastered.		4 in. Thick.	8 in. Thick.	12 in. Thick.	
$\frac{1}{2}$ brick	·52	·49	·43	...	...	...	...
1 "	·37	·36	·33	·31	·29	·26	·25
$1\frac{1}{2}$ "	·29	·28	·26	·25	·23	·21	·21
2 bricks	·25	·24	...	·22	·20	·19	·19
$2\frac{1}{2}$ "	·22	·21	...	·19	·18	·17	·16
3 "	·19	·18	...	·17	·16	·15	·14
$3\frac{1}{2}$ "	·16	·16	...	·15	·14	·13	·13
4 "	·14	·14	...	...	...	...	·12
$4\frac{1}{2}$ "	·12	·12	...	...	...	...	...
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

TABLE VI.—LOSS OF HEAT THROUGH STONE WALLS IN BRITISH THERMAL UNITS PER SQUARE FOOT OF SURFACE PER HOUR, PER DEGREE DIFFERENCE OF TEMPERATURE

Total Thick- ness of Wall.	Sandstone.	Limestone.	Total Thick- ness of Wall.	Sandstone.	Limestone.
12 in.	·45	·49	32 in.	·26	·28
16 „	·39	·43	36 „	·24	·26
20 „	·35	·38	40 „	·22	·24
24 „	·31	·35	44 „	·21	·23
28 „	·28	·31	48 „	·19	·21
(1)	(2)	(3)	(1)	(2)	(3)

In Tables V and VI, and for column (2) in Table VII, Prof. Rietschel states that the values should be increased as follows:—

Ten per cent where the exposure is a northerly one, and the winds are important factors.

Ten per cent when the building is heated during the day-time only, and the building is not an exposed one.

Thirty per cent when the building is heated during the day-time only, and the building is exposed.

Fifty per cent when the building is heated during the winter months intermittently, with long intervals of non-heating.

The following table gives two estimates of the losses through glass and other surfaces in British Thermal Units per hour, per degree difference of temperature, per square foot of surface:—

TABLE VII

Kind of Surface.	Authorities.	
	Recknagel and Rietschel.	German Government Standard.
Single windows	1·03	1·09
Double „	·472	·518
Single skylight	1·092	1·118
Double „	·492	·621
Doors	·410	·414
Fireproof floor	—	·124
„ ceiling	—	·145
Plaster 1·6 to 2·6 in. thick ...	·615	—
„ 2·6 „ 3·2 „ „ ...	·492	—
(1)	(2)	(3)

The amount of heat absorbed by warming the air for the ventilation of a building next requires consideration. Irrespective of special inlets and outlets, the atmosphere of a room will be changed slowly by diffusion

through walls, floor, ceiling, and crevices; this mode of ventilation, however, is inadequate, and when estimating the quantity of air that passes through a room it is not usual to make any allowance for that which is thus diffused.

The velocity of air through flues can be determined by an anemometer. From the mean of a number of readings calculations are made. The volume of air discharged in cubic feet per second can be obtained by multiplying the area of cross section of the flue or duct in square feet by the velocity in feet per second.

It is impossible to give an exact table of the number of air changes that will take place, as the modes of ventilating buildings and the sizes and uses of apartments are so varied, but as a rule the air ought to be changed not less than three times per hour.¹

The following table gives the weight and volume of dry air at different temperatures, atmospheric pressure constant at 29·92 in. of mercury, and the volume at 32° being 1:—

TABLE VIII

Temp. Deg. F.	Volume.	Weight of a Cubic Foot in lb.	Temp. Deg. F.	Volume.	Weight of a Cubic Foot in lb.	Temp. Deg. F.	Volume.	Weight of a Cubic Foot in lb.
0	·935	·0864	60	1·057	·0764	100	1·139	·0710
12	·960	·0842	62	1·061	·0761	102	1·143	·0707
22	·980	·0824	70	1·078	·0750	112	1·163	·0604
32	1·000	·0807	72	1·082	·0747	122	1·184	·0682
42	1·020	·0791	82	1·102	·0733	132	1·204	·0671
52	1·041	·0776	92	1·122	·0720	142	1·224	·0660

Heat Units.—Before the amount of heat that is absorbed by the different cooling bodies can be ascertained, a heat unit must be decided upon. In Great Britain and America the unit adopted is known as the *British Thermal Unit*, which is the amount of heat required to raise 1 lb. of water from 39° to 40° F. The heat unit is often considered to be the amount of heat necessary to raise 1 lb. of water 1° from any temperature. Although this practically holds good for low and medium temperatures, it is not correct for high temperatures. The heat unit is written in the contracted form B.T.U.

The heat unit adopted in most of the Continental countries, and termed the *Calorie*, is the amount of heat required to raise 1 kilogram of water 1° Centigrade.

1 calorie is equal to 3·968 British Thermal Units.

1 kilogram equals 2·2046 lb. (avoirdupois).

Specific Heat.—Different substances have different powers of absorbing and giving out heat; this is usually expressed by saying that different substances have different specific heats. The *specific heat* is the ratio between the quantity of heat required to raise the temperature of any

¹ See Section VII, Chapter VIII.

substance 1° , and that required to raise an equal amount of water through the same temperature. Water is taken as the standard, its specific heat being unity or 1. The specific heat of air = $\cdot 238$.

Air-warming for Ventilation.—We are now able to find the heat necessary to warm the air required for ventilating buildings.

Example.—Suppose air enters an apartment at 30° F. The weight of 1 cu. ft. of air at 30° is $\cdot 081$ lb., and $\cdot 081 \times \cdot 238$ (specific heat of air) = $\cdot 01928$ unit, the amount of heat required to raise 1 cu. ft. of air 1° .

Therefore 1 B.T.U. will be sufficient to raise $\frac{1}{\cdot 01928} = 51\cdot 86$ cu. ft. of air from 30° to 31° . When air enters a room at 30° F., and it is raised to a given temperature, the number of B.T.U. required can be found by multiplying the number of cubic feet of air by the range of temperature through which it is raised, and dividing the product by $51\cdot 86$.

Total Heat Losses.—It is seldom necessary in the United Kingdom to calculate separately the heat lost through internal walls, floors, and ceilings; the chief losses which are included in calculations are those due to glass surfaces, external walls, and ventilation.

It would appear that the most satisfactory results would be obtained if the total heat losses were calculated in heat units per hour, and just sufficient heating surface were allowed as would emit an equal number of units in the same time. For all practical purposes, however, if the chief losses already enumerated are considered, and 10 per cent of their total is added for minor and unforeseen heat losses, the final result will be sufficiently accurate. The total heat lost from a building may be expressed by a formula.

$$U = (\cdot 021 C n + 1\cdot 14 G + \cdot 4 W) (T - t) \quad (7)$$

Where U = B.T.U. absorbed per hour.

„ C = capacity of room in cubic feet.

„ n = number of air changes per hour.

„ G = exposed glass surface in square feet.

„ W = exposed wall surface in square feet.

„ T = internal temperature of room in deg. F.

„ t = temperature of external air in deg. F.

The constant $\cdot 021$ is the fraction of a heat unit required to warm 1 cu. ft. of air from 30° to 31° F. with 10 per cent added. The constants $\cdot 4$ and $1\cdot 14$ are for one-brick walls and single windows respectively, and are taken from Tables V and VII, with 10 per cent added in each case.

The heat emitted by hot-water pipes depends chiefly upon the difference in temperature between the water in the pipes and the air in contact with their external surfaces, the velocity of the air passing over them, the velocity of the circulation, and the diameters and arrangement of the pipes. A plain horizontal pipe will be considered the standard for comparing the various forms of heating surfaces.

When a heating surface is fixed in an apartment, the air is warmed in two ways, viz.: by radiant and by convected heat. The heat emitted by radiation depends largely upon the kind of heating surface, whilst that

emitted by convection is not affected in this way, but varies with the height and size of the surface, and the velocity of air over it.

The total amount of heat emitted by horizontal pipes is given in the following table:—

TABLE IX.—HEAT UNITS EMITTED PER HOUR PER SQUARE FOOT OF SURFACE

This table is taken from *Heating and Ventilating Buildings*, by Prof. Carpenter.

Difference of Temperature Degrees F.	Amount per Degree Difference of Temperature.				Total per Square Foot per Hour.			
	Horizontal Pipe Diameter.				Horizontal Pipe Diameter.			
	6 in.	4 in.	2 in.	1 in.	6 in.	4 in.	2 in.	1 in.
	Radiator Height.				Radiator Height.			
	40 in. Massed Surface.	40 in. Thin.	24 in. Massed	12 in. Thin.	40 in. Massed Surface.	40 in. Thin.	24 in. Massed.	12 in. Thin.
10	·55	·62	·66	·85	5·50	6·7	6·6	8·5
20	1·11	1·25	1·32	1·72	20·2	24·9	26·4	34·4
30	1·18	1·34	1·42	1·84	35·0	39·7	42·7	55·2
40	1·24	1·40	1·48	1·92	49·6	56·2	59	77
50	1·29	1·46	1·54	2·01	64·5	73	77	100
60	1·33	1·50	1·58	2·06	79·8	90	95	124
70	1·36	1·54	1·63	2·12	95·2	108	113	148
80	1·40	1·58	1·67	2·18	112	127	133	173
90	1·43	1·63	1·72	2·24	128	147	153	199
100	1·47	1·66	1·77	2·28	147	167	175	228
110	1·51	1·71	1·80	2·34	166	188	198	257
120	1·54	1·74	1·84	2·39	184	208	219	287
130	1·57	1·78	1·88	2·44	203	230	242	318
140	1·61	1·81	1·91	2·48	223	252	266	346
150	1·64	1·84	1·94	2·53	244	276	291	378
160	1·66	1·87	1·97	2·57	265	300	316	410
170	1·69	1·91	2·02	2·62	286	324	341	443
180	1·72	1·94	2·05	2·65	307	348	367	475
190	1·75	1·98	2·09	2·71	330	375	393	512
200	1·78	2·01	2·12	2·76	356	403	415	552
225	1·87	2·12	2·24	2·91	420	477	500	650
250	1·97	2·23	2·35	3·06	493	557	587	762
275	2·07	2·34	2·47	3·22	563	637	670	872
300	2·17	2·45	2·58	3·37	654	742	780	1020
325	2·27	2·55	2·70	3·50	740	840	882	1150
350	2·37	2·67	2·82	3·66	835	945	995	1295
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

Amount of Heating Surface for Warming Dwelling Houses, Works, and Similar Buildings (Hot Water).—According to Table IX, column (7), the amount of heat emitted by a horizontal hot-water pipe 4 in. in diameter per square foot of surface per hour, when the difference between the

temperature of the water in the pipes and that of the air in the building is 110° F., is 188 B.T.U.; and $\frac{188}{110} = 1.71$ B.T.U. per degree difference of temperature per square foot of surface per hour, as stated in column (3). The heat losses can be found by Formula (7), and if the total amount is divided by the number of heat units emitted per square foot of heating surface per hour, the total amount of pipe heating surface required is obtained.

From the following formulæ the amount of pipe heating surface is directly obtained:—

Let u = the amount of heat emitted from the heating surface per degree of difference of temperature per hour per square foot of surface.

„ P = temperature of water in pipes.

„ T = temperature of air in apartment.

„ t = temperature of external air.

„ C = capacity of room in cubic feet.

„ n = number of air changes per hour.

„ G = area in feet of exposed glass surface.

„ W = area in feet of exposed wall surface.

„ R_1 = radiating surface required for ventilation in square feet.

„ R_2 = radiating surface required to supply heat absorbed by walls.

„ R_3 = radiating surface required to supply heat absorbed by glass.

„ R = total heating surface required.

$$R_1 = \frac{.021 C n (T - t)}{u (P - T)}; R_2 = \frac{.4 W (T - t)}{u (P - T)}; \text{ and } R_3 = \frac{1.14 G (T - t)}{u (P - T)}.$$

$$R = \{ .021 C n + .4 W + 1.14 G \} \left\{ \frac{T - t}{u (P - T)} \right\} \quad . \quad . \quad (8)$$

(For internal temperatures which do not exceed 70° F.)

The formula can be simplified when some of the values are assigned. Thus, if $T = 60^\circ$, $t = 30^\circ$, $P = 170^\circ$, and $u = 1.8$ —

$$R = \{ .021 C n + .4 W + 1.14 G \} \left\{ \frac{60 - 30}{1.8 (170 - 60)} \right\}.$$

$$R = (.021 C n + .4 W + 1.14 G) \times .1515 \quad . \quad . \quad (8a)$$

If each of the constants is multiplied by .1515 and its reciprocal obtained, the rule can be further simplified. Thus:—

$$\frac{1}{.021 \times .1515} = 311, \quad \frac{1}{.4 \times .1515} = 16.5, \text{ and } \frac{1}{1.14 \times .1515} = 5.7.$$

To facilitate calculations, the fractional parts of the numbers can be omitted without serious error, and if the above values are taken as 310, 16, and 6, the simplified rule becomes—

$$R = \frac{C n}{310} + \frac{W}{16} + \frac{G}{6} \quad . \quad . \quad . \quad (8b)$$

Rule (8b) may also be written as follows:—

Cubic capacity of room $\times$ air changes per hour $\div$ 310	}		=	Total heating surface required.
Exposed wall surface in square feet ... $\div$ 16				
Exposed glass surface in square feet ... $\div$ 6				

Rule (8b) is computed for the following conditions only: Water in pipes, 170° F.; temperature in room, 60° F.; external air, 30° F. If the temperature of the water in the pipes is less than 170°, a greater amount of heating surface will be required, assuming that the remaining conditions are unaltered.

In heating systems the water has its temperature diminished as it travels from the boiler or heater, and it will often be found that the temperature is less than 170° F. When such is the case, the calculations must be based upon a lower temperature, say 160° F., or less if necessary. Another rule will be computed to satisfy the lower temperature of 160° F., the external and internal air temperatures remaining as before.

The heat emitted by a 3-in. horizontal pipe surface will be 1·7 B.T.U. per square foot per degree difference of temperature per hour, when the water in the pipe is 160° F. and the air of the room 60° F.

Therefore by substituting values in Formula (8)—

$$R = \{ \cdot 021 C n + \cdot 4 W + 1 \cdot 14 G \} \left\{ \frac{60 - 30}{1 \cdot 7 (160 - 60)} \right\}.$$

$$\therefore R = (\cdot 021 C n + \cdot 4 W + 1 \cdot 14 G) \times \cdot 1764 \quad . \quad . \quad (8c)$$

Multiplying the constants separately by ·1764, and afterwards obtaining their reciprocals, the following whole numbers are found:—270, 14, and 5.

Therefore the simple rule becomes, when the water temperature is 160° F. and the external and internal air 30° F. and 60° F. respectively—

$$R = \frac{C n}{270} + \frac{W}{14} + \frac{G}{5} \quad . \quad . \quad . \quad . \quad . \quad . \quad (8d)$$

Rule (8d) may be written thus:—

Cubic capacity of room × air changes per hour ÷ 270	} = heating surface required.
Exposed wall surface in square feet ... ÷ 14	
Exposed glass surface in square feet ... ÷ 5	

The following will show the difference in the heating surface required for a room that is maintained at a temperature of 60° F. when the outside air is 30° F., and when the water in the pipes is 170° F. and 160° F. respectively.

Example.—A room contains 3000 cu. ft. of space, the air is changed three times per hour, area of exposed wall surface 180 sq. ft., and of glass 60 sq. ft.

When Temperature of Water is 170° F. Rule (8b) is used.	Where Temperature of Water is 160° F. Rule (8d) is used.
$R = \frac{C n}{310} + \frac{W}{16} + \frac{G}{6}.$	$R = \frac{C n}{270} + \frac{W}{14} + \frac{G}{5}.$
$R = \frac{3000 \times 3}{310} + \frac{180}{16} + \frac{60}{6}.$	$R = \frac{3000 \times 3}{270} + \frac{180}{14} + \frac{60}{5}.$
$R = 29 + 11 \cdot 25 + 10.$	$R = 33 \cdot 3 + 12 \cdot 85 + 12.$
$\therefore R = 50 \text{ sq. ft. of pipe surface.}$	$\therefore R = 58 \text{ sq. ft. of pipe surface.}$

In the examples, 16 per cent more heating surface is required when the water is 160° F. instead of 170° F. The formulæ given and the worked examples show that the results are considerably affected by variations of the water temperature. The actual heating surface is also affected in a similar manner when the temperature of the air of a room is raised. In other words, the nearer the temperatures of the heating surfaces and the apartment approach each other the greater the amount of heating surface required.

Extra Surfaces for Radiators, &c.—As the formulæ are computed for exposed horizontal pipes, the following extra surfaces will be required if pipes in channels or radiators are used:—

Add 5 per cent for plain 1-column radiators when about 38 in. high.

" 15	"	2	"	"	"	"
" 20	"	3	"	"	"	"
" 25	"	4	"	"	"	"
" 40	"	flue radiators.				
" 40	"	pipes fixed in channels.				

A greater allowance than that given above is required for ornamental radiators.

Also add 10 per cent for buildings in exposed situations.

Also add 10 per cent for rooms with northern aspect.

The simple rules (8*b*) and (8*d*), as already shown, are limited in their application, and in order to make them applicable for a wider range of temperatures a table of constants is appended, which is taken from Jones's *Heating by Hot Water, Ventilation, and Hot-Water Supply*.

TABLE X.—CONSTANTS FOR VARYING TEMPERATURES IN ORDINARY BUILDINGS

Inside Tempera- ture, F.	External Temperatures, F.													
	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	
40°	.8	.75	.65	.56	.5	.45	.38	.34						
45°	1.0	.89	.88	.72	.62	.55	.48	.42	.36					
50°	1.2	1.1	1.0	.88	.77	.68	.60	.54	.46	.4				
55°	1.4	1.3	1.2	1.1	1.0	.88	.76	.68	.6	.5	.44			
60°	1.7	1.6	1.5	1.4	1.3	1.1	1.0	.88	.76	.65	.55	.48		
65°	2.0	1.9	1.8	1.6	1.5	1.3	1.2	1.1	1.0	.88	.75	.62	.52	
70°	2.5	2.3	2.1	2.0	1.8	1.7	1.5	1.4	1.3	1.12	1.0	.86	.75	
75°	3.0	2.8	2.7	2.5	2.3	2.1	2.0	1.8	1.6	1.5	1.3	1.15	1.0	
80°	3.8	3.6	3.4	3.1	2.9	2.7	2.5	2.2	2.0	1.9	1.7	1.5	1.3	
85°	4.6	4.4	4.2	4.0	3.8	3.6	3.3	2.9	2.7	2.5	2.2	2.0	1.9	
90°	5.7	5.5	5.3	5.0	4.7	4.5	4.3	4.0	3.8	3.4	3.0	2.8	2.5	
100°	8.3	8.2	8.1	8.0	7.9	7.7	7.5	7.0	6.4	6.0	5.7	5.4	4.8	

In this country a heating installation is usually required to be capable of maintaining a temperature of 60° F. when the outside air is 30° F., but in America and some of the Continental countries an inside temperature of 70° F. is required when the outside air is zero.

In Table X an inside temperature of 60° and external temperature of 30° are taken as unity. To use the constants, first find the heating

surface according to rules (8b) and (8d), and afterwards multiply the result by the constant which satisfies the inside and outside temperatures.

Example.—Find the heating surface required to warm a room which has a capacity of 3000 cu. ft., air changed three times per hour, 180 sq. ft. of exposed wall surface, and 60 sq. ft. of glass, when the inside temperature required is 75° F., with the external air at 20° F.

This example is the same as the previous one, with the exception of the internal and external temperatures. The amount of pipe surface obtained by rule (8b), when $P = 170^\circ$, $T = 60^\circ$, and $t = 30^\circ$, was 50 sq. ft. Upon looking in Table X for the constant which satisfies inside and outside temperatures of 75° F. and 20° F. respectively, 2.3 will be found.

$\therefore 50 \times 2.3 = 115$ sq. ft. of pipe surface required.

If the room is to be heated by plain three-column radiators, the total radiating surface required = 115 + 20 per cent = 115 + 23 = 138 sq. ft.

The following table gives the relative amounts of heating surface for low-pressure hot-water apparatus, based upon the cubic capacity of a building. This method of calculating heating surface is not very accurate, but it is sometimes convenient for approximate determinations. The usual temperatures to which different buildings are heated are shown in column 2. The amount of surface is for an external temperature of 30° F., and for a temperature of the water in the pipes not less than 160° F.

TABLE XI.—DIRECT RADIATION

Kind of Apartment Warmed.	Temperature required.	One Square Foot of Pipe Surface Warms—
Workshops and Factories ...	50° F.	130 cu. ft
Warehouses	55°	100 "
Churches and Assembly Rooms ...	60°	86 "
Living Rooms	65°	55 "
Entrance Halls	70°	42 "
Rooms for drying goods at higher temperatures... ..	75°	34 "
	80°	27 "
	85°	22 "
	90°	18 "
	100°	10 "

CHAPTER VI

LOW-PRESSURE HOT-WATER APPARATUS: BOILERS

Many failures in heating systems have been due to the overrating of boilers, and it is to be deplored that a better standard of rating does not exist among British boilermakers. The general method of rating is that of considering 1 sq. ft. of direct boiler heating surface as capable of heating a number of feet run of 4-in. pipes; this number varies from 25 to

35 ft. of pipe, according to the maker's discretion. This method is not satisfactory, as the number of B.T.U. emitted per square foot of heating surface varies considerably in different parts of the system, and the value of the boiler surfaces varies also within wide limits.

Some of the irregularities in catalogues are most marked. An example may be given. A boiler catalogued to heat 500 ft. of 4-in. pipes is also said to be capable of raising 100 gal. of water from 40° to 212° F. in one hour. One foot run of 4-in. pipe will emit, under ordinary conditions, about 190 B.T.U. per hour; then $190 \times 500 = 95,000$ B.T.U. emitted by 500 ft. in 1 hour. The heat units necessary to raise 100 gal. of water from 40° to 212° F. in 1 hour will be $100 \times 10 \times (212 - 40) = 172,000$. The difference between the two values $= 172,000 - 95,000 = 77,000$ B.T.U. Now, if the boiler transmits only 95,000 units in the first case, it cannot transmit 77,000 more units in the same time in another case when the rate of firing is the same.

The boiler mentioned is supposed to have $14\frac{1}{4}$ sq. ft. of direct heating surface. The area of the fire bars does not exceed 1 sq. ft. Now, suppose 9 lb. of good coal, which has a calorific value of 14,000 B.T.U. per pound, is burned per hour, the total heat in the coal would be $14,000 \times 9 = 126,000$ units, or 46,000 B.T.U. less than are required to raise 100 gal. of water from 40° to 212° F. The boiler under consideration would not transmit through its plates to the water more than 50 per cent of the total units contained in the coal. Upon this basis the total B.T.U. utilized are 63,000, and the average number of units transmitted in one hour through each square foot of boiler surface is $63,000 \div 14.25 = 4421$. Taking again 1 ft. run of 4-in. pipe as capable of emitting 190 B.T.U. per hour, the actual boiler power with the given rate of firing is easily obtained; thus $63,000 \div 190 = 332$ ft. run of 4-in. pipe. This is 34 per cent less than the catalogue rating. If the rate of fuel consumption were raised, the fuel could not be burned in such a boiler satisfactorily.

For economical working, small boilers are not so good as larger ones, and few low-pressure hot-water boilers can be considered really economical. These boilers usually require a slow rate of combustion, and the film of hot gas that accumulates on the boiler surfaces is not easily moved; hence it is doubtful if many of the best low-pressure boilers with a slow rate of combustion in actual work transmit to the water much more than 50 per cent of the heat contained in the fuel they consume. Unless the boiler surfaces are well arranged and kept clean, even 50 per cent efficiency will not be obtained. The general efficiency of a boiler largely depends upon the following conditions:—1. Size. 2. Rate of firing. 3. Condition of flues. 4. Size and height of chimney. 5. Regulation of draught. 6. Ratio of grate area to boiler surface.

The durability of boilers is affected by the way they are used, the chemical action of the water, and whether saline or other matter is deposited on their heating surfaces or not.

The amount of heat transmitted through boiler plates depends not only upon the extent and nature of their surfaces, but also upon the amount and kind of fuel burnt. The fuel consumed in low-pressure heating

boilers varies from 3 to 12 lb. per square foot of grate area per hour. If an ordinary case is considered, where 6 lb. of fuel are burned per square foot of grate per hour, an idea can be formed of the actual amount of heat transmitted through the plates; and when that is known, the number of square feet of radiating surface that can be effectively supplied can be ascertained.

Example.—If a boiler contains $1\frac{1}{2}$ sq. ft. of grate surface, and absorbs 40 per cent (*i.e.* $\frac{2}{5}$) of the heat in the fuel, which has a calorific value of (say) 12,000 B.T.U.; find the amount of ordinary radiating surface that the above rate of firing will supply.

A plain single-column radiator will emit about 160 B.T.U. per hour per square foot of surface.

The total heat available in the fuel consumed is $12000 \times \frac{2}{5} \times 1\frac{1}{2} \times 6 = 43,200$ B.T.U.; and as each square foot of radiator requires 160 units, the extent of surface required is $43,200 \div 160 = 270$ sq. ft.

The heating surfaces of boilers may be divided into two classes, viz.

direct and indirect. The direct surfaces receive heat by direct impact of the flames, radiant heat from the fire, and the heated products of combustion. The indirect surfaces depend chiefly upon the heated gases from the fire. The amount of heat transmitted by indirect surfaces is comparatively small; and when these surfaces are relatively large,

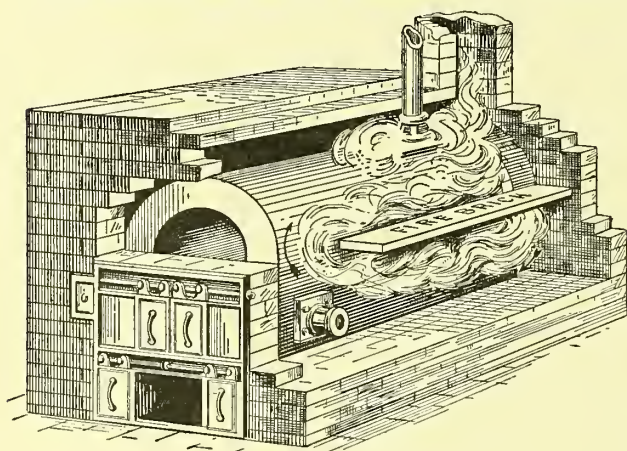
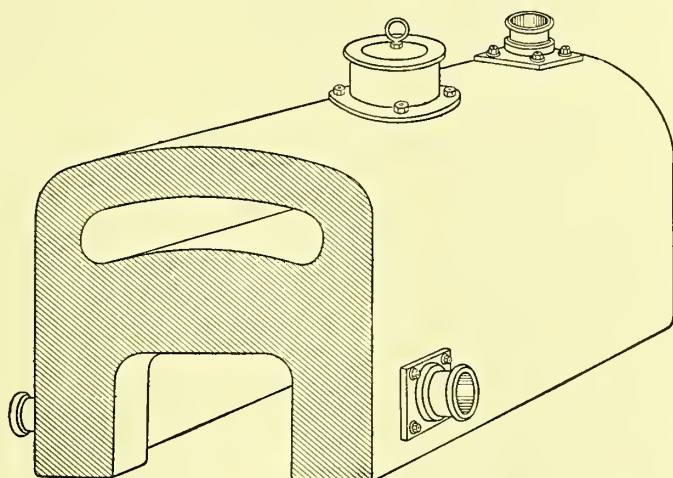


Fig. 856.—Saddle Boiler

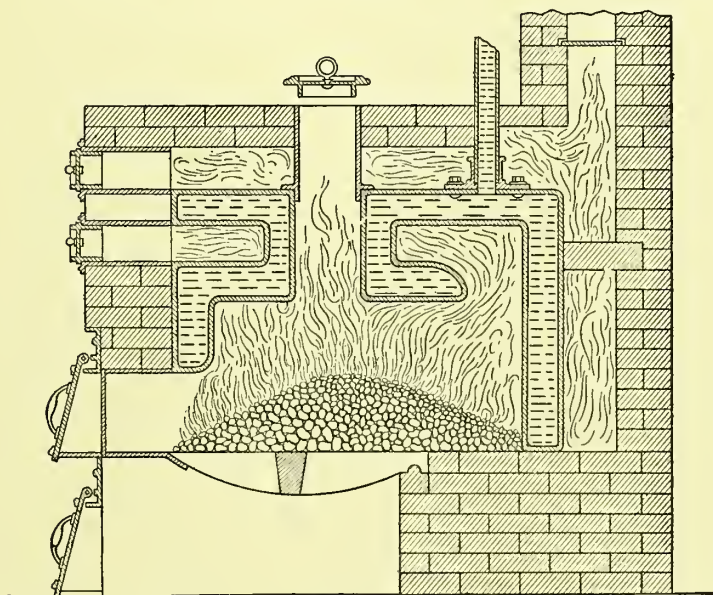
the average amount of heat absorbed per unit area of boiler surface is much reduced. Boiler heating surfaces are arranged horizontally, vertically, or obliquely; they may be either plain, circular, or corrugated in form. Horizontal surfaces facing downwards to the fire take up the greatest amount of heat, and similar surfaces facing upwards absorb the least heat. The latter result is due to the amount of soot which the surfaces collect, and the slowness with which heat is conducted by water in a downward direction.

The saddle boiler formerly found the greatest favour, and is still largely used, especially for horticultural work, and answers very well where less than 1000 sq. ft. of heating surface is required. It is made of $\frac{5}{16}$ - or $\frac{3}{8}$ -in. wrought-iron plates, and in a great number of sizes. The external dimensions vary from 18 in. in length, 14 in. in width, and 13 in. in height to 84 in. in length by 30 in. in width and 27 in. high; their powers are listed as being capable of heating from 150 to 1600 feet of 4-in. pipes. Fig. 856

shows how the flues and settings are frequently arranged. The advantages of this class of boiler are that it is simple and easily managed, can be well banked up with fuel and left for a considerable time without attention, and



No. 1



No. 2

Fig. 857.—“Colonial” Boiler: View and Section

the heating surfaces are easily cleaned. The chief disadvantage of saddle boilers is the great amount of space they occupy in proportion to their heating power; they are also less economical in fuel consumption than some of the modern boilers. The water space of these boilers varies from 2 to 4 in. in width; but to be efficient in working the width should not

exceed 3 in. The fire and heated gases pass from the interior of the boiler round the back and return towards the front along the lower part, and again pass back over the top of the boiler and up the chimney. The top of the boiler is not of much value for heating water, for reasons already explained. The side flues should not be much more than 4 in. in width, in order that the heated gases may be made to impinge against the boiler sides, but should not be less than 3 in., or they will soon fill with soot. A damper should be fixed in order to regulate the draught.

Terminal waterway-end wrought-iron flue boilers are better than saddle boilers, but they are more expensive. The surfaces of these boilers are better arranged to baffle the flames, and absorb a greater amount of heat. The "Colonial" (fig. 857) has a large amount of direct heating surface. Terminal-end boilers are made in a number of sizes, and (according to the

makers' catalogues) heat from 490 to 3350 ft. of 4-in. pipes. Fig. 857, No. 2, shows the brickwork setting of the "Colonial". A disadvantage of terminal-end boilers is the difficulty of effecting repairs. The welded joints should be in a position where they are not subjected to the fiercest heat; otherwise unequal expansion and contraction at the joints, due to the extra thick-

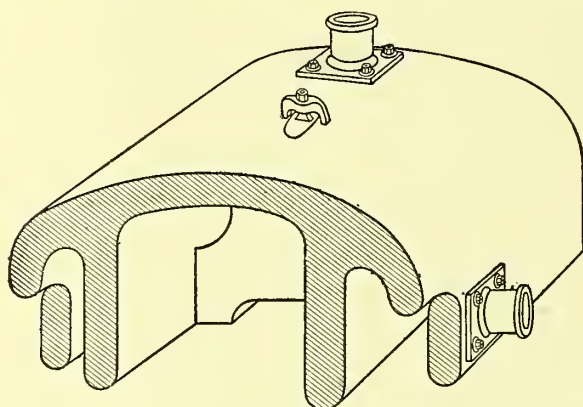


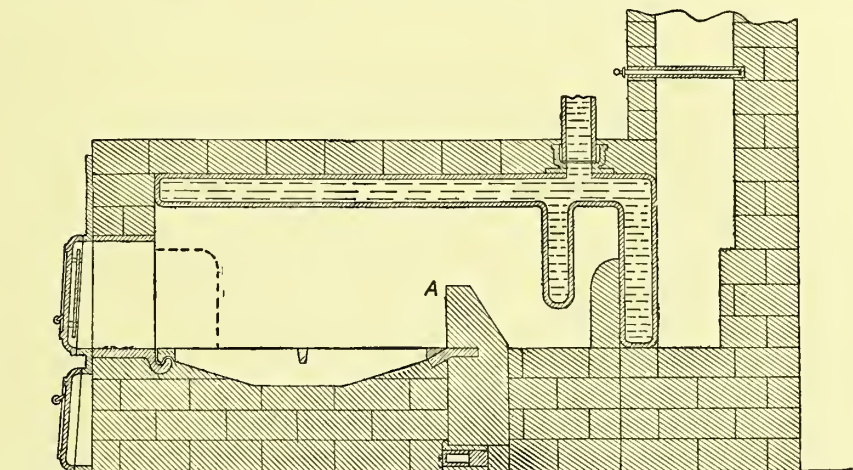
Fig. 858.—The "Delta" Boiler

ness of metal, may cause them to leak. Like saddle boilers, they occupy a lot of space, and are made up to 7 ft. in length.

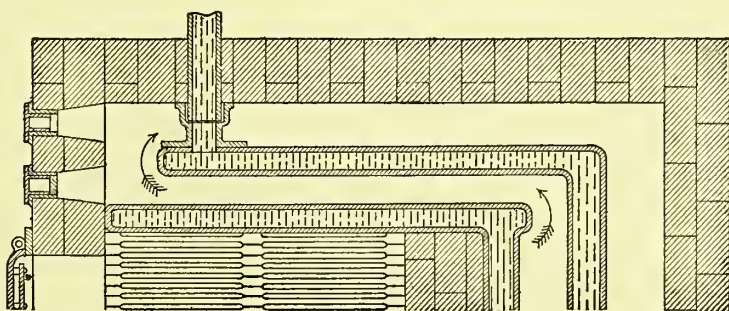
A boiler known as the "Delta" (fig. 858) has some good features. It is very suitable for horticultural work where there is a difficulty in sinking a deep boiler pit, owing to shallow drainage of the subsoil. It is simple in construction, made with waterway-end and return side flues, and possesses in a large degree the advantages of the ordinary terminal-end boiler without its disadvantages. Every part is easily examined by turning it upside down. The brickwork settings of the "Delta" are shown in fig. 859. The ridge A serves the useful purpose of deflecting the flames against the upper surfaces, and increases the efficiency of the boiler. The flow pipe is taken off the boiler at the point where it receives the fiercest heat, so that free circulation is not unduly retarded. These boilers are made from 30 in. to 7 ft. in length, and the height of the largest size is 26 in.

For heating large buildings, such as schools, &c., the "Trentham" Cornish boiler is much used. This class of boiler is specially suitable for high buildings. It is circular in form, and its shape renders it capable of withstanding high pressures. The products of combustion take a circuitous path, first passing from the combustion chamber under the lower

portion of the boiler, and afterwards over the upper portion to the chimney. Fig. 860, No. 1, shows the fire brick which separates the lower from the upper flue. This boiler, with the bridge and combustion chamber properly arranged, is the most powerful of the types already shown. The "Trentham" requires a high chimney in order to secure a good draught. The bridge A (No. 2) serves to reduce the size of the opening, so that the speed of the gases will be accelerated in passing through it, and whirling



No. 1



No. 2

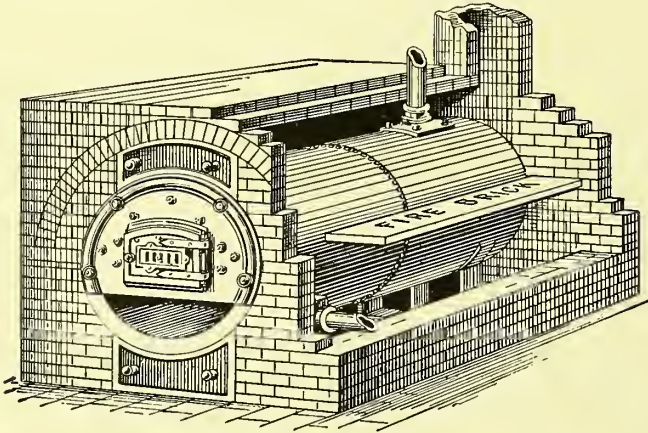
Fig. 859.—Section and Half Plan of "Delta" Boiler with Brickwork

motions and eddies produced in consequence. This action tends to promote a more thorough mixing of the air drawn through the furnace and the heated gases, and causes combustion to be more complete. The space B is the combustion chamber, where the gases mix and are consumed. The heating surface can be increased by fixing cross tubes in the combustion chamber B, and a waterway bridge at A. Trentham boilers are made in sizes from 4 to 18 ft. in length, and from 2 ft. 8 in. to 5 ft. in diameter. These boilers are rated as heating from 900 to 10,500 feet of 4-in. pipe, but are greatly overrated for normal working conditions.

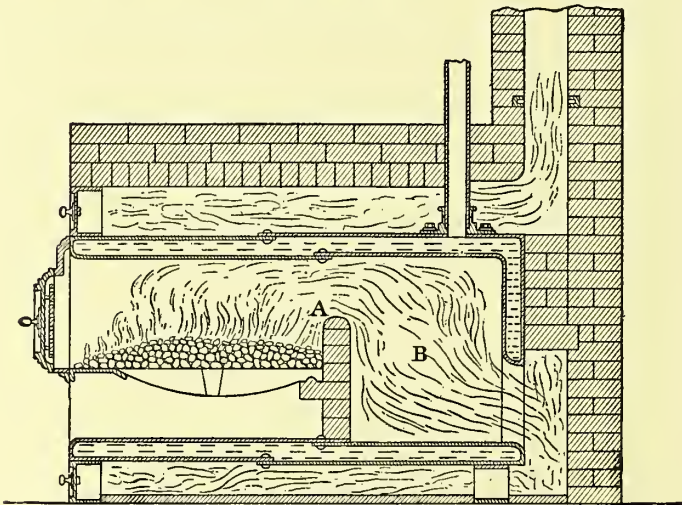
To heat small places, and where a cheap apparatus is required, the boiler may be formed by a coil of wrought-iron tube set upon a grate

and built round with brickwork. This arrangement answers fairly well; but if water is drawn off frequently, and replaced with water that contains saline matter, the coil is liable to become charged with sediment, which will bring about its destruction by causing the coil to be burned.

All boilers should be provided with mud lids, so that any deposit can be removed periodically. When the waterways of boilers terminate on a



No. 1



No. 2

Fig. 860.—“Trentham” Cornish Boiler

level with the fire bars, any saline matter from temporarily hard water (unless removed while in the state of sludge) will become baked into a hard mass, and the boiler is liable to be burned through or cracked at the part where the deposit has formed. Boilers supplied with temporarily hard water should have their waterways carried below the level of the fire bars, in order to make them more lasting, especially when such water is often drawn off from the system.

As the success of a boiler largely depends upon clean surfaces, sufficient soot doors should be built in the brickwork in order that the flues can be properly cleaned.

Copper boilers are occasionally used for heating purposes; but if they are required for warming buildings only, and the water used does not unduly attack cast iron, their extra cost is seldom justifiable. It is a prevalent idea that a copper boiler will do far more work than one of an equal size made of iron, owing to the conductivity of copper being greater than that of iron.

With boilers the transmission of heat due to the higher conductivity of a metal is a minor consideration. The greatest resistance to the passage of heat is that offered by the film of soot or carbon deposited on the boiler surfaces; and when that resistance is overcome, the heat is quickly passed through the metal walls of the boiler, whether they be copper or iron. As a matter of fact, there is little difference in the amount of heat transmitted through different metal surfaces of the same area and thickness—other conditions being equal—when each surface is covered with a layer of soot.

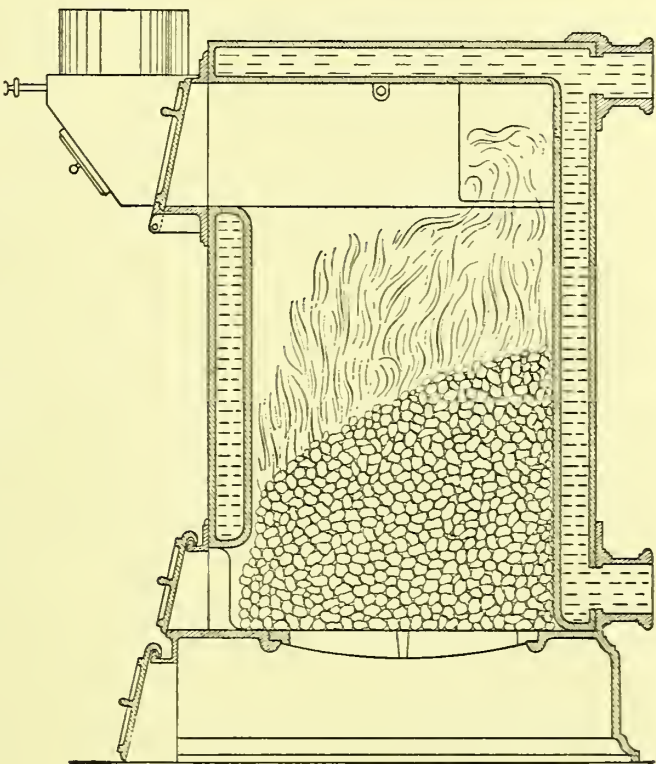


Fig. 861.—Independent Boiler with Waterway Top

Independent boilers are gradually superseding those which are set in brickwork, owing to the small space they occupy and their compactness of form; they are also more convenient to fix and repair. The first cost is a little higher than that of those set in brickwork; but when the cost of the brick setting is added, the difference is not very great. These boilers have the advantage of portability, and are made of cast iron, wrought iron, steel, and copper. The large sizes are usually composed of a number of sections, while the small sizes may be either in one or more pieces. The advantages of sectional boilers are that they can be conveyed through small openings, such as doorways, and are easy to handle and fix. Cast-

iron sectional boilers are superseding those made of wrought iron. The superiority of cast-iron over wrought-iron boilers is due to the fact that the former are not so liable to corrode, and are consequently more durable. Cast-iron boilers are made for consuming different kinds of fuel: some are suitable for soft bituminous coals, while others are only suitable for smokeless fuel, such as anthracite or coke.

A self-contained boiler with only vertical heating surfaces is wasteful, as a great amount of heat is drawn directly into the chimney or flue; the position of the outlet pipe is also conducive to waste. The only advantage such a boiler has to recommend it is its low initial cost. The "Finsbury"

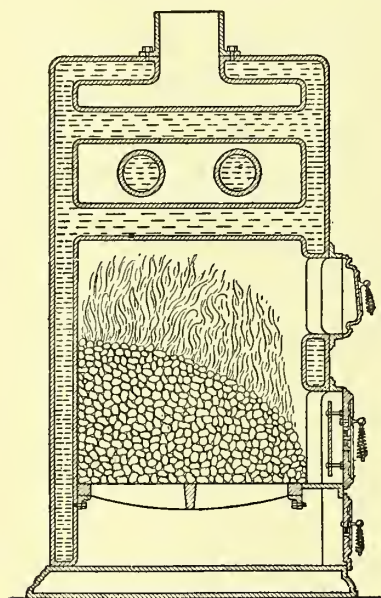


Fig. 862.—Independent Boiler with Cross Tubes

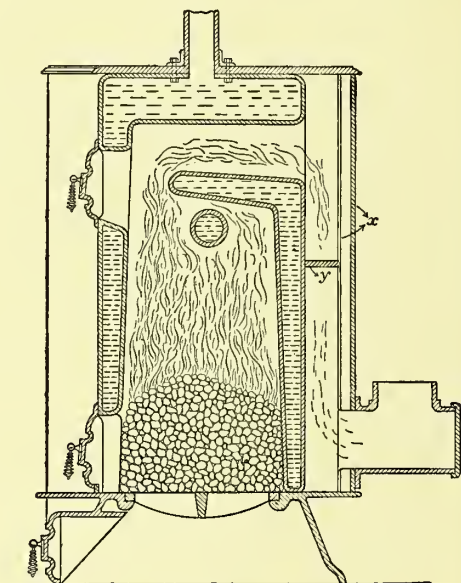


Fig. 863.—"Pioneer" Boiler

type (fig. 861) is better, as the flames are caused to impinge against a waterway top. It is fairly serviceable for small installations, and is cheap and made in sizes which are catalogued to heat up to 650 ft. of 4-in. pipe. The largest sizes would be rather wasteful in fuel.

Dome-top boilers are like the last, but with dome tops, the flow being taken from the crown. They are made in a large number of sizes, catalogued to heat from 150 to 2150 ft. of 4-in. pipe. Like many others, they are considerably overrated. Boilers of this class have heating surfaces only at the sides and top, and therefore cannot be economical, as the flames are able to pass directly into the flue, and the products of combustion pass away at a very high temperature.

In order to increase the efficiency of these boilers, cross tubes are added, as shown in fig. 862. Such a boiler is very powerful, and is suitable for heating large buildings; it is made of wrought iron, and the cross tubes are welded to the shell. The number of tubes fixed in a boiler depends upon its height. Cross tubes make very efficient heat-

absorbing surfaces, and the fuel is utilized to better advantage, as the flames and heated gases strike against the different surfaces. The fire box is large, and will hold sufficient fuel for a long time. The external surfaces of these boilers should be covered with a good non-conducting material to prevent loss of heat. Boilers like fig. 862 are made in sizes from 40 in. in height and 18 in. in diameter to over 80 in. in height and 60 in. in diameter, and are listed to heat from 320 to 5600 ft. of 4-in. pipe. The waterway is shown carried below the fire bars, and forms a receptacle for deposit.

In Lumby's "Pioneer" boiler (fig. 863) the products of combustion, after passing between the direct heating surfaces, descend towards the bottom through the space between the outer casing and waterway sides. The hot

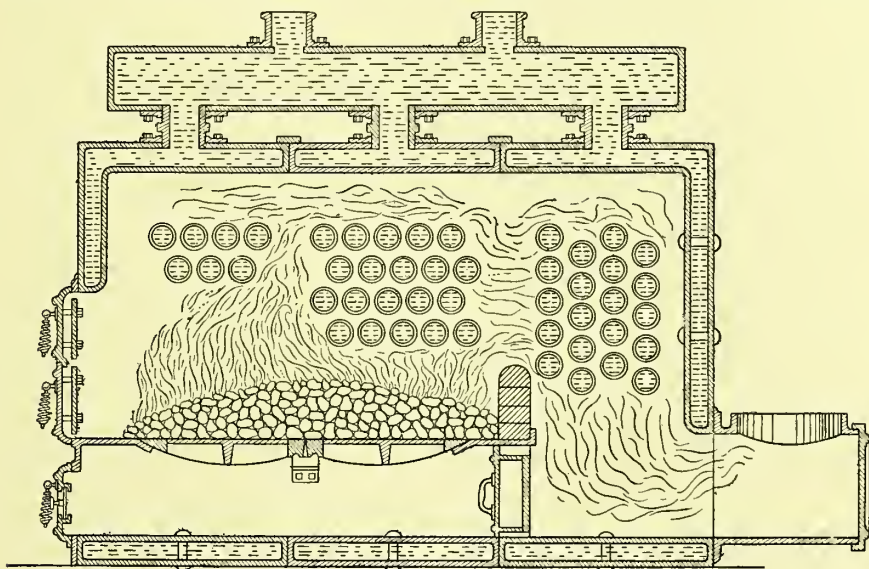


Fig. 864.—"European" Sectional Boiler

gases are caused to take an indirect course to the outlet by the iron baffle-plate *y*, which is fixed midway down the flue and extends towards the front, so that the hot gases can be further cooled before discharging into the smoke pipe. This indirect surface is very useful, but one has to be careful not to put too high a value upon it. The boiler is provided with a double jacket *x* packed with non-conducting material.

The "European" sectional self-contained boiler by Hartley and Sugden (fig. 864) can be made to any size, and built up of any number of sections to suit requirements. The tubes are of wrought iron expanded into the waterway sides. The flow-pipe connection of each section is intercepted by a horizontal pipe, which is sometimes termed a "header", and the return to each section is similarly treated. A boiler 48 in. $\times$ 30 in. $\times$ 42 in. is listed to heat 1200 ft. of 4-in. pipes, while one 81 in. $\times$ 54 in. $\times$ 54 in. is stated to heat 5500 ft.

Cast-iron boilers, to be satisfactory, must be simply constructed, so that the metal can be obtained throughout equal in thickness. There is now no

difficulty in obtaining a casting that will withstand fluctuations of heat and cold without being cracked.

A sectional cast-iron boiler made by the National Radiator Company is shown in fig. 865. This type is made in different sizes, and listed to

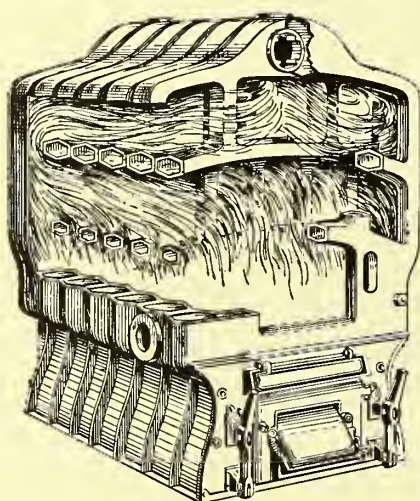


Fig. 865.—National Radiator Company's Sectional Boiler

suit installations containing from 800 to 6450 sq. ft. of heating surface. The sections are joined together with strong tapered push nipples, and wrought-iron tie rods hold the sections in position. The sections are vertically arranged, so that as the size of the boiler is increased by additional sections, the grate area is proportionally increased. The water-ways are numerous, and present thin sheets of water to the action of the flames. This boiler may be used for burning a soft kind of coal, and it may also be provided with either plain or rocking fire bars. In another boiler, made by the same firm, the flues and grate area are rather smaller, and are proportioned to burn a smokeless fuel.

The fire pot in each is large, and will hold sufficient fuel to keep up a steady heat for ten to twelve hours; and the construction of the boilers is such as to minimize waste of heat. The heating surfaces are easily freed from soot, and every part is accessible.

An American boiler, square in shape, and made by the Griffing Iron Company, Ltd., is shown in fig. 866. It is composed of a number of cast-iron sections set in a vertical position, with flanges or beads cast on them, so as to butt together, and form horizontal flues, which extend the whole length of the boiler. These sections, which are $1\frac{1}{2}$ in. in width, are bolted together by means of heavy tapered nipples and wrought-iron tie rods. The arrangement presents a large amount of heating surface by subdividing the water spaces into such thin layers; each section has water on its inside, while the whole of the outer surfaces are exposed to the action of the fire. The grates provided with these boilers are of the rocking type. The direction of the flames and heated gases, after coming in contact with the surfaces directly exposed to the fire, is up the back and through the middle flues (formed by the flanges on the sections) towards the front, and then back through the top flues to the outlet. The boiler is made in various sizes, which are

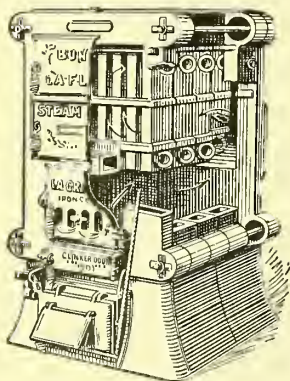


Fig. 866.—Griffing Iron Company's Sectional Boiler

rated to supply from 575 to 4725 sq. ft. of heating surface.

When this form of boiler is required to burn soft bituminous coal, it is slightly modified by omitting the flanges on the bottom of the sections, and fixing the smoke box in front instead of at the back. In the modified form the heat rises directly from the fire box, circulates around the lower ends of the sections, passes to the back and up, and forward through the top flue to the smoke pipe. When soft bituminous coal is used for boilers whose flues form very circuitous paths the deposit of soot is great, and the boilers require a lot of attention.

Another type of sectional boiler (fig. 867) is known as the "Daisy" heater. The sections are placed over each other, and each connects with a waterway column. The flames are baffled in passing through the various flues, and impinge upon the horizontal surfaces. The first, third, and fifth sections have several openings through which the products of combustion pass, while in the second and fourth sections only one opening is provided. The areas of the openings are proportional in each case. Owing to the way these surfaces are arranged, a soft bituminous coal is not suitable, and either coke or anthracite should be used.

Fig. 868 shows the "Challenge" boiler, in which also the sections

are fixed one above the other. A large amount of heating surface is directly over the fire, and the tubes are slightly inclined to facilitate circulation. The sections are machine-faced, and communicate with each other at the four corners, where vertical circulation takes place. The sections are tied together with long wrought-iron bolts, which pass through the waterway corners. The fire pot can be made sufficiently large to hold fuel for ten to twelve hours, and may be obtained with rocking bars. These boilers are listed to heat from 500 to 7000 ft. of 4-in. pipe; they will, however, require a good draught, if all the heating surfaces are to be rendered effective, especially when seven or eight sections are fixed over the fire box.

To determine the size of boiler sufficiently powerful for installations, the usual custom is to depend largely upon a catalogue, and to select a boiler that is listed to be large enough for a system containing from

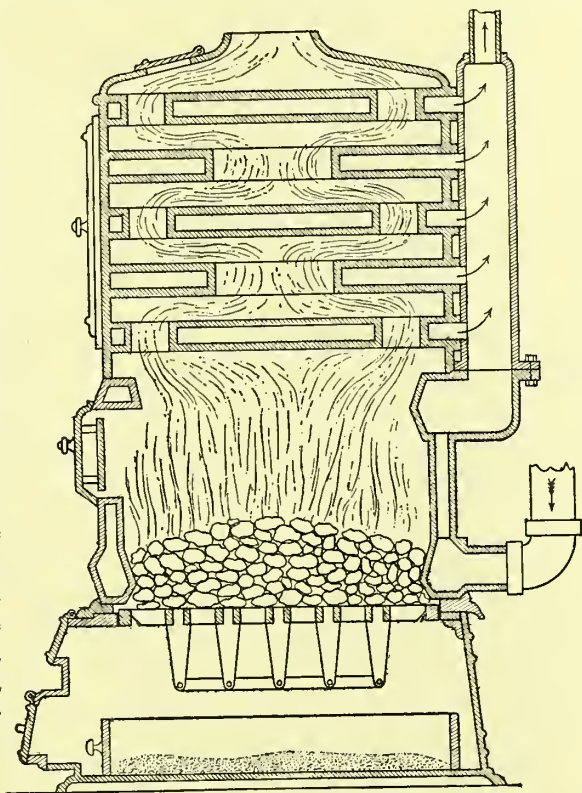


Fig. 867.—Warden King & Son's "Daisy" Heater

The average value for $U = 160$.

- $c = .5$ to $.65$ for good sectional self-contained boiler.
 „ $.4$ „ $.55$ „ Cornish Trentham boiler.
 „ $.4$ „ $.5$ „ saddle boilers.
 „ $.5$ „ $.6$ „ vertical boilers with cross tubes.
 „ $.35$ „ $.45$ „ vertical plain dome-top (self-contained) boiler.

The fuel consumption (w) for different boilers for the given values of c will be approximately as follows:—

- $w = 6$ to 9 for brick-set boilers.
 $w = 7$ to 10 for sectional boilers with winding flues.
 $w = 8$ to 12 for boilers with straight draught.

The total boiler heating surface can be approximately obtained by multiplying the grate area by the following values:—

- 8 to 10 for self-contained dome-top boilers (small size).
 12 to 16 for self-contained boilers with cross tubes (large size).
 14 for boilers similar to fig. 865.

If a boiler is required for 2500 sq. ft. of radiation, and a type similar to fig. 862 is selected—

$$a = \frac{RU}{wf c} = \frac{2500 \times 160}{12 \times 14000 \times .6} = 3.96 \text{ sq. ft. of grate.}$$

The heating surface of the boiler should be approximately $3.96 \times 15 = 59.4$ sq. ft.

These calculations are based upon the assumption that the fuel used has a calorific value of 14,000 B.T.U. per pound, and that 12 lb. of fuel are burned on each square foot of grate area per hour.

The following table gives the calorific value of different fuels for each pound weight (Molesworth):—

TABLE XII

Coal, average	...	14,000 B.T.U.	Coal, Lancashire Steam	13,900 B.T.U.
„ Welsh Steam	...	16,000 „	„ Newcastle	... 14,000 „
„ Welsh Medium	...	13,900 „	Coke	... 12,500 „
„ Scotch	...	13,500 „	„ (gas)	... 10,600 „

The fire bars of boilers are cast in different forms to suit the kind of fuel to be burned. For very small coal the bars require to be closer together than when large pieces of fuel are used. The ordinary straight fire bars are usually the most satisfactory, and last a fairly long time, and are easily replaced. Grates are sometimes made in one casting, but these often twist with the heat, and are more liable to fracture than a more simple form of grate. Many of the American boilers, and some of British make, are supplied with rocking or shaking grates (fig. 869). Although these are often recommended on the ground that a fire is more easily cleaned and controlled, they have not found much favour in this country;

in fact, in some cases where rocking bars have been first supplied, they have afterwards been replaced with good plain fixed bars.

The boiler chimney is of some importance, as failures are occasionally traceable to it, especially when it is too small. The shape of a chimney has an influence upon its draught, circular chimneys offering the least resistance. For small boilers cast-iron pipes are often used, but they should not be less than 5 in. in diameter. Small boilers are usually more

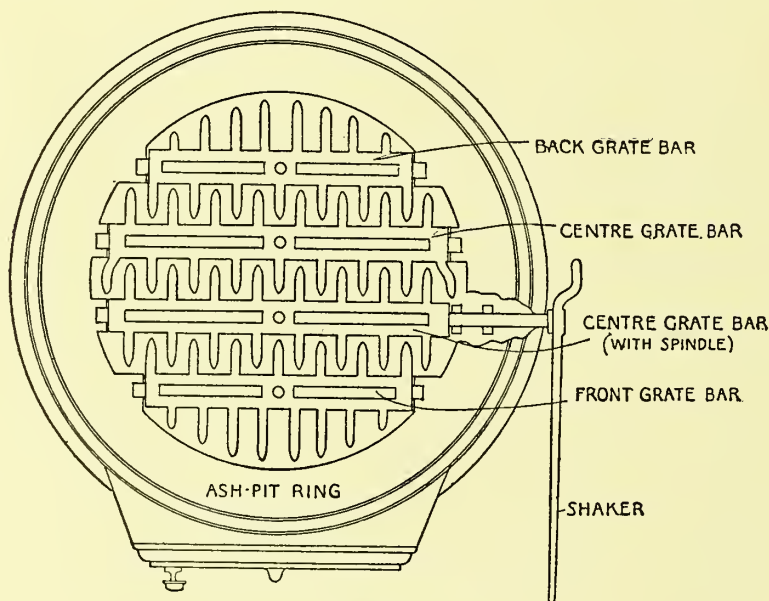


Fig. 869.—Plan of Rocking Grate

successful if the smoke pipe can be turned into a brick chimney. Brick-set boilers require higher chimneys than self-contained straight-draught boilers, and the height of a chimney should always exceed the length of the horizontal flues.

The draught of a chimney can be found by the empirical formula—

$$D = \frac{2.42\sqrt{h}(T - t)}{T} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Where D = draught of chimney in feet per second.

„ h = height of chimney in feet above fire bars.

„ T = internal temperature of chimney.

„ t = temperature of external air.

Example.—A chimney is 25 ft. high, the average internal and external temperatures being 150° F. and 50° F. respectively. What draught has this chimney?

$$D = \frac{2.42\sqrt{h}(T - t)}{T} = \frac{2.42 \times 5 \times 100}{150} = 8.06 \text{ ft. per second}$$

To find the size of chimney suitable for a hot-water heating installation, the following empirical formula may be used:—

$$E = \frac{0.3 H}{\sqrt{h}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Where E = effective area of chimney in square feet.

„ H = horse-power of plant, 1 horse-power being equivalent to 200 sq. ft. of radiating surface, that is, $H = .005 R$.

„ h = height of chimney in feet.

The effective area of a chimney is less than its actual area, owing to the soot deposited upon its surfaces.

The actual diameter of the chimney is supposed to be 2 in. larger than the effective diameter for installations containing over 700 ft. of radiation, and 3 in. larger for apparatus consisting of 600 sq. ft. of radiation and less.

In order to make the formula (11) directly applicable, it will require modification.

Let d = actual diameter of circular chimney in inches.

„ R = total radiation in square feet.

$$\text{Since } E = \frac{.3 H}{\sqrt{h}} \text{ and } H = .005 R, \quad E = \frac{.0015 R}{\sqrt{h}}.$$

And since $d = 12 \sqrt{\frac{E}{.7854}} + 3$ or 2, we obtain, by substituting the value of E given above, $d = 12 \sqrt{\frac{.0015 R}{.7854 \sqrt{h}}} + 3$ or 2.

$$\therefore d = 12 \sqrt{\frac{.002 R}{\sqrt{h}}} + 3 \text{ or } 2 \quad . \quad . \quad . \quad . \quad (12)$$

Example 1.—A system consists of 9000 sq. ft. of radiation, height of chimney 36 ft. Find the diameter required.

For over 700 sq. ft. of radiation—

$$d = 12 \sqrt{\frac{.002 R}{\sqrt{h}}} + 2 = 12 \sqrt{\frac{.002 \times 9000}{\sqrt{36}}} + 2.$$

$$\therefore \text{diameter of chimney} = (12 \times 1.73) + 2 = 22.76 \text{ in.}$$

The length of one side of a square chimney may be considered equivalent to the diameter of a circular one.

Example 2.—An installation has 500 sq. ft. of radiation; height of chimney, 25 ft. What must be the diameter of the chimney?

$$d = 12 \sqrt{\frac{.002 R}{\sqrt{h}}} + 3 = 12 \sqrt{\frac{.002 \times 500}{\sqrt{25}}} + 3.$$

$$\therefore d = (12 \times .44) + 3 = 8.28 \text{ in. diameter.}$$

Automatic Draught-regulators for Hot-water Boilers.—To control the fuel consumption and automatically adjust the degree of heat required, a

damper regulator can be used. The regulator is usually connected with two dampers, one of which is fixed to the boiler, and controls the amount of air admitted to the fire; while the other is fixed to the flue or outlet

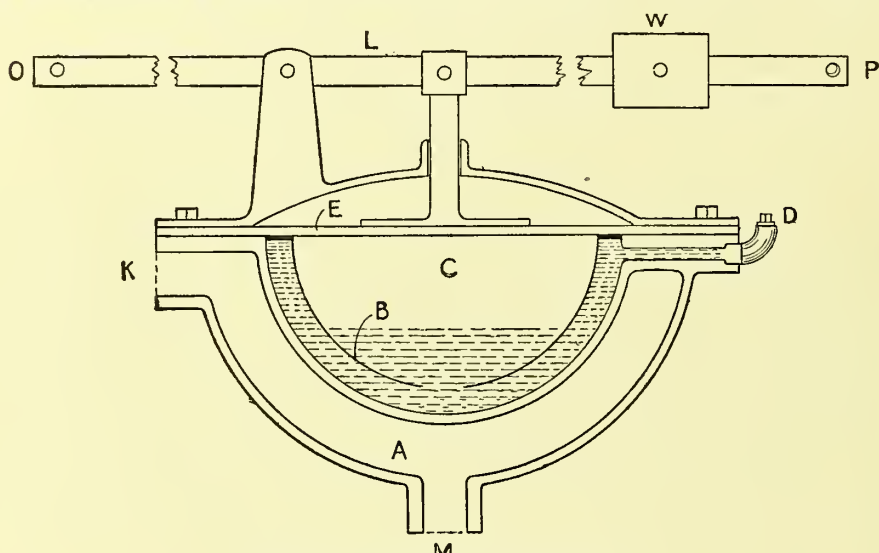


Fig. 870.—Lawler's Automatic Damper Regulator

pipe, and serves to check or accelerate the draught by either being opened or closed.

Fig. 870 shows Lawler's automatic damper regulator, which consists of the following parts:—A, a channel through which water circulates; B, a space filled with a sensitive liquid; C, air space in communication with cavity B; a filling hole at D, and a rubber diaphragm E, which is connected with the lever L. From the main flow pipe a branch is taken, and joins the regulator at K, and the return connection is joined at M. The action is as follows. The hot water circulating through the channel A imparts heat to the sensitive liquid in B, and causes it to expand and dislodge a small portion into the chamber C; the confined air is thus further compressed, and as the increased pressure exerts its force on the diaphragm E, the latter rises and operates the lever L. The diaphragm, on being raised, causes the end O of the lever to fall and close the damper which adjusts the air supply to the boiler; at the same time the end P rises and opens the damper in the flue, and allows air to enter the chimney without first passing through the fire.

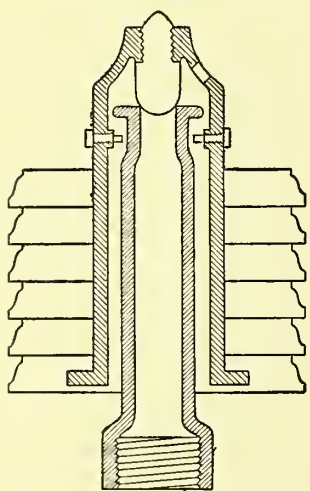


Fig. 871.—Dead-weight Safety Valve

The weight w serves to balance the lever and to regulate the temperature at which the appliance should operate. When the water in the flow pipe

begins to cool, the diaphragm sinks, reverses the order of the dampers, and accelerates the draught.

The present design of automatic regulators for hot-water boilers cannot be considered satisfactory, as they are too slow in operation.

Safety Valves.—To avoid explosions, a good type of safety valve should be fixed to each system. These fittings have not been so extensively used for hot-water heating apparatus as they might have been; but since the introduction and common use of cast-iron boilers their use is almost imperative, as the explosion of a cast-iron boiler would prove more disastrous than the explosion of a wrought-iron boiler. The safety valve should be fixed on the top of the boiler, and tested periodically to see that it is in working order. A good form of dead-weight safety valve is illustrated in fig. 871, but a good lever-and-weight safety valve may be used.

CHAPTER VII

LOW-PRESSURE HOT-WATER APPARATUS: SYSTEMS OF PIPING

Three Systems of Piping.—Low-pressure hot-water installations are erected upon what are known as the *one-pipe*, *two-pipe*, and *overhead* systems; the last is also a one-pipe system. In the one-pipe system (fig. 872) the inlet and outlet to and from each radiator are joined to the same pipe, while in the two-pipe system (fig. 873) the outlet connection joins the



Fig. 872.—One-pipe System: Connections to Radiators

return pipe. The main circuit of the one-pipe system is everywhere of the same size, while in the two-pipe system the mains are graded, that is, reduced in size as a portion of the heating surface is supplied.

The one-pipe system is a good arrangement when the circuits are not very long, and has the advantage that **short-circuiting** is impossible. The chief drawback of the two-pipe system is its liability to short-circuit, especially when the pipes are dipped or trapped. This trouble may also be experienced when the pipes are too small in size, or where the circulation is sluggish. Each radiator on this system forms a by-pass or short-circuit between the flow and return mains, and as the natural tendency for the water is to take the most direct and easiest course, one or more radiators

at the far end of the circuit may be very imperfectly heated. Short-circuiting is a very common defect, and may take place in any two-pipe installation where branches or subsidiary circulations are arranged, if precautions are not taken to avoid it.

Connections to Radiators.—In figs. 872 and 873 the flow connection to each of the first radiators, A, is at the top, while that to each of the others,

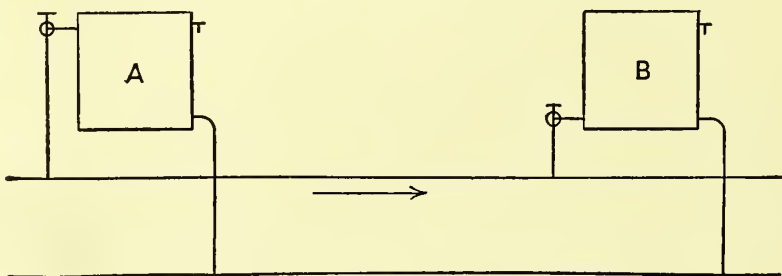


Fig. 873.—Two-pipe System: Connections to Radiators

B, is at the bottom. Both methods are considered satisfactory, but the top connection is perhaps the better so far as the circulation is concerned, while the bottom connection is neater.

Very often little details have an important bearing upon the general efficiency of a system. An example is illustrated in fig. 874, where two radiators are fixed about 4 ft. apart. Under ordinary conditions, when connecting to a single radiator, the horizontal connections are kept as short

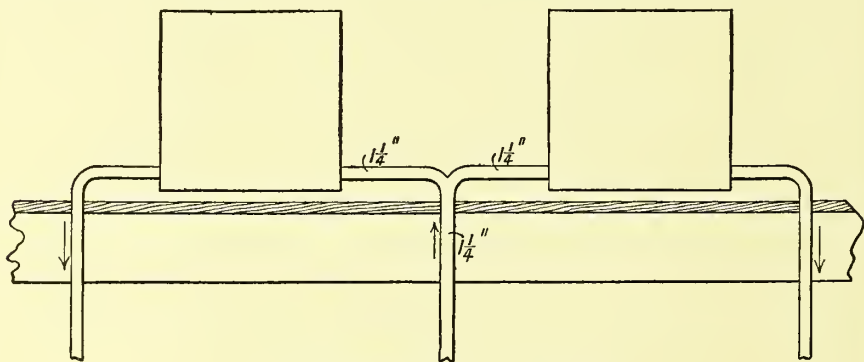


Fig. 874.—Connections to Two Radiators

as possible in order to reduce friction. In fig. 874, the riser, which is $1\frac{1}{4}$ in. in diameter, is fixed to supply both radiators. This arrangement increases the length of the horizontal pipe, but instead of fixing a diminishing tee and making each connection a size smaller, the pipes should be $1\frac{1}{4}$ in. in diameter throughout.

The one-pipe system is well suited for heating buildings of one story. If the building is large, two or more complete circuits can be arranged. Fig. 875 shows how the ground floor of a building can be heated when the mains are fixed beneath the ceiling of the basement. In this case the

only pipes in sight in the rooms heated are the connections to the radiators. The portion of the main up to the point A acts as the flow pipe, while the part from A to the boiler acts as the return pipe. An air pipe can be taken from the highest point of the main or from the radiator as shown. If an air pipe is not desirable, an ordinary or automatic air cock can be attached to the radiator, but if an ordinary air cock is used, it will be necessary to open it periodically in order to release the air which accumulates at the top of the radiator.

There will be a marked difference between the temperature of the water

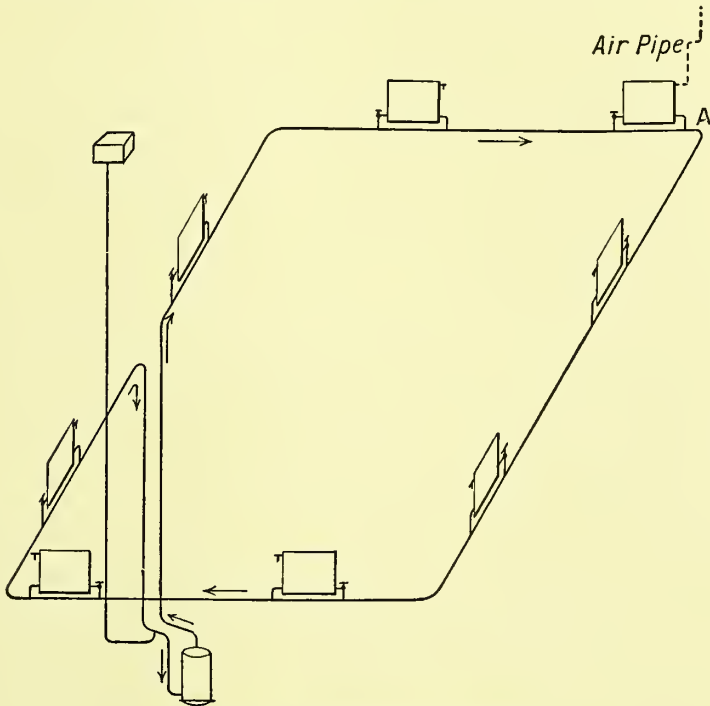


Fig. 875.—One-pipe System : Single Circuit

in the first radiator and that in the last, and in order to equalize the distribution of heat from the various points, the sizes of radiators should be suitably graded. Where several radiators are fixed in one large room, grading is not so necessary, if the hottest surfaces are fixed in the most exposed positions. Should the arrangement shown in fig. 875 be fixed in connection with several rooms, the radiators in the rooms near the end of the circuit would require to be larger than those at the beginning of the circuit to emit equal amounts of heat.

For warming small buildings of two floors, a simple system can be arranged as shown in fig. 876. The flow pipe is first taken to the top floor, its highest point being at A, where an air pipe is fixed; from this point the remainder of the circuit forms the return. The pipes are shown passing round three sides of the building and running under the

radiators, which can be readily obtained to allow for this. The amount

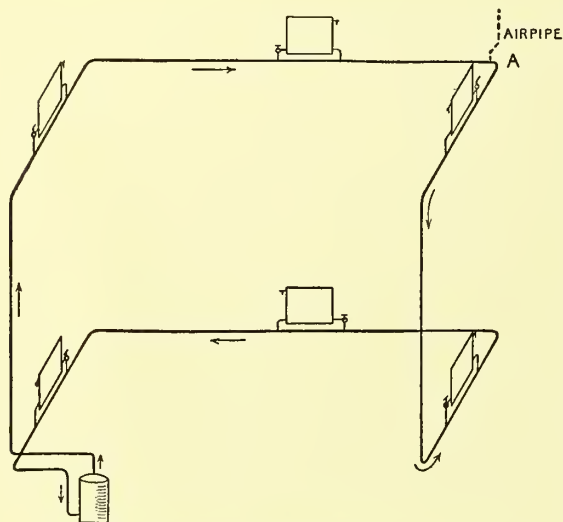


Fig. 876.—One-pipe System: Single Circuit on Two Floors

Secondary Circuits (fig. 877) is often adopted for large buildings of two or more stories. Where possible the radiators should be arranged directly

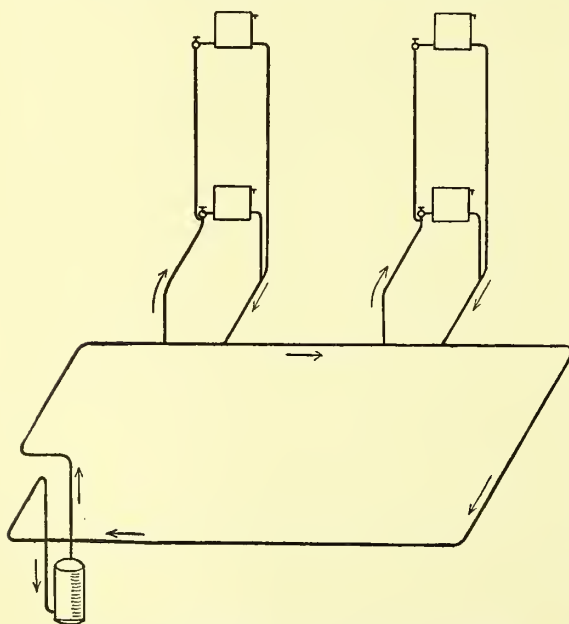


Fig. 877.—One-pipe System with Two Secondary Circuits

of heating surface to warm equally different parts of a building, when the piping is arranged as in fig. 876, must be a little more liberal on the bottom than on the top floor, owing to the latter receiving the hottest water. When computing the heating surface necessary to warm a room, the exposed mains must be taken into consideration. Hot-water pipes are not often used for warming private houses, where direct heating surfaces are required, as radiators are more easily arranged.

The One-pipe System with Secondary Circuits (fig. 877) is often adopted for large buildings of two or more stories. Where possible the radiators should be arranged directly over each other, in order to diminish the number of risers and the length of the horizontal branches. The risers, of course, will require to be proportionate in size to the amount of work they have to do. The flow riser is taken from the top of the main, while the return riser delivers into the same pipe but at the side. This arrangement usually ensures the circulation taking place in the right direction. In fig. 877 the main is supposed to pass round the building, so that the risers can be taken directly to the fittings required. This method of piping may require a little extra pipe

when compared with another arrangement, but it has the advantage of avoiding dips, and a good circulation can be obtained. When warming

buildings by this method, it is often necessary to divide them into sections and provide a separate main circuit for each part.

The **Overhead or Drop System** can be advantageously used for high buildings. Fig. 878 shows how the pipes are arranged. The flow pipe from the boiler is conducted to the top of the building, and from this point horizontal pipes are arranged so that they can be "dropped" close to the radiators. To these vertical return pipes the radiators are connected, inlets and outlets being joined to the same pipe. The radiators are fixed, if possible, directly over each other on the different floors, and the vertical return pipes are intercepted in the basement by horizontal mains, which join the main return. An advantage possessed by this system is the large amount of vertical piping, which creates a rapid circulation, and allows the pipes to be reduced in size. The pipes require to be graded, so that each pipe will properly perform the work allotted it.

The radiators on the overhead system do not require air cocks, as any air given off by the water can escape by way of the inlet connections. Moreover, air is chiefly given out from water during the period of heating, and as the air travels along with the heated water directly to the highest point, the largest proportion of it escapes at the outlet provided.

An installation arranged on the two-pipe system is shown in fig. 879. The mains are intended to be fixed in a basement, and the risers are fixed in a similar manner to those of the one-pipe system, the only difference being that the return risers are joined with the main return. This arrangement possesses one advantage over the one-pipe system, especially when radiators are fixed on two or more floors, as the cooled water from the radiators is delivered into the return main, and therefore does not mix with and cool the water which has to supply other heat-emitting surfaces.

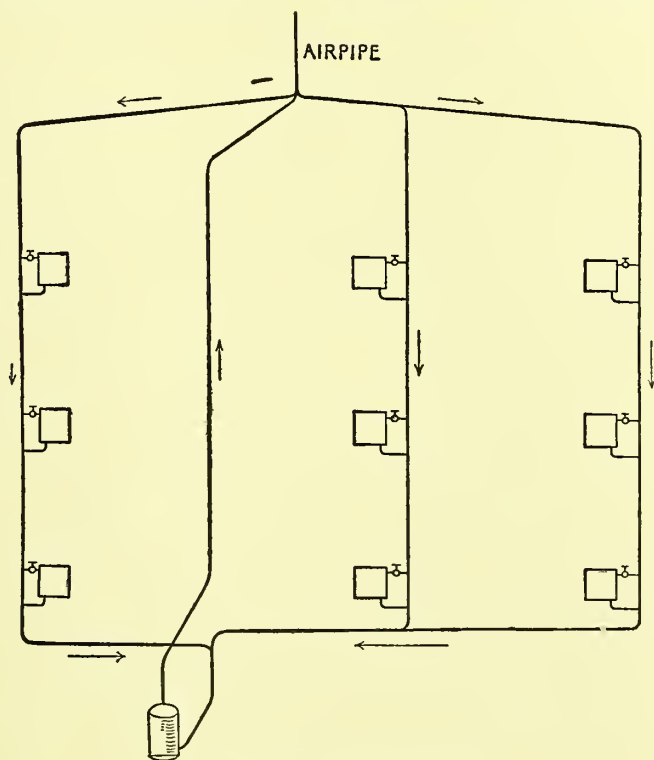


Fig. 878.—Overhead or Drop System

Another installation is shown in Plate XLI, and although the details do not differ materially from the diagrams given in the text, the illustration will be useful as an example of a working drawing in which the pipes, radiators, &c., are shown in relation to the walls, windows, and other parts of the structure.

The two-pipe system is successful where good pitches can be obtained for the mains, and where the pipes are properly sized, connections well arranged, and dips avoided; if these conditions cannot be complied with,

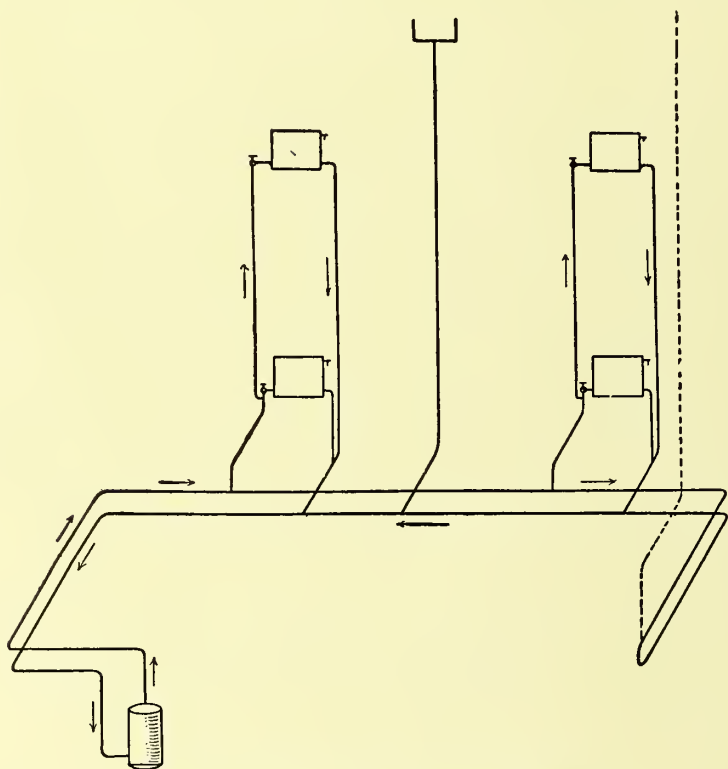
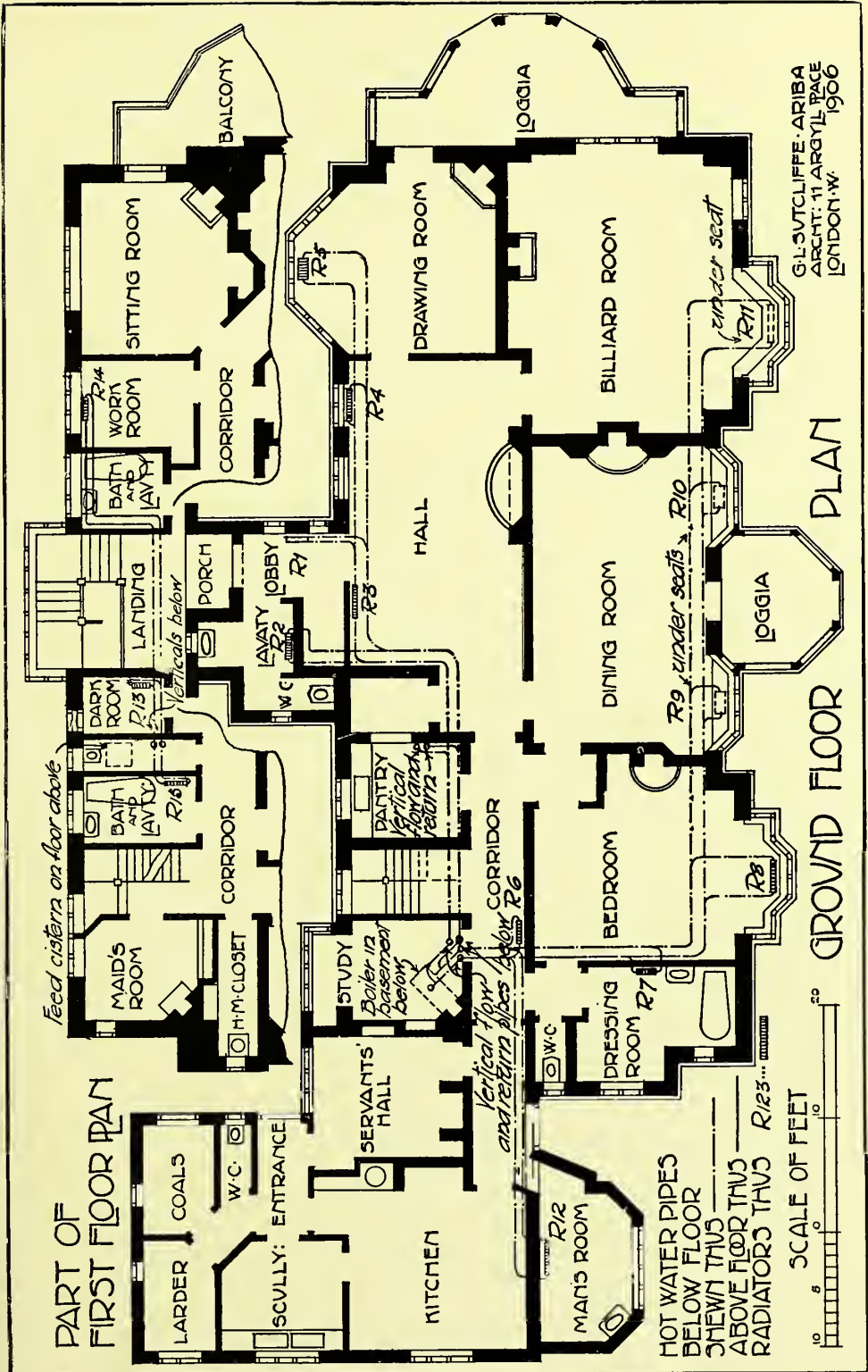


Fig. 879.—Two-pipe System with Two Secondary Circuits

short-circuiting will undoubtedly more or less take place. It is usually more costly than a one-pipe system, as the length of piping is greater; on the other hand, much of the piping is smaller in size.

Hotels, &c.—In large boarding-houses, hotels, and similar establishments, bedrooms are frequently warmed by radiators fixed in the corridors. If the radiators on the different floors can be fixed immediately over each other, the overhead system can in many cases be installed; or, if the building consists only of two or three floors, the one-pipe system, similar to fig. 877, with risers to the different points, may better suit the case. In the overhead system the horizontal distributing pipes are run on the top floor, and for the other system suggested the mains are fixed in the basement.



PLAN OF HOUSE SHOWING LOW-PRESSURE HOT-WATER HEATING APPARATUS

If the building will admit of neither arrangement, it may be necessary to run the horizontal pipes along the corridors by the skirting, as in fig. 880, which illustrates two floors of a building heated by a single circuit. In the drawing, four dips are shown, so that the pipes will clear the doorways. An ordinary two-pipe system for such a case would be a complete failure. A good circulating head is necessary to force the circulation round so many obstructions, and in some cases it will be necessary for this reason to carry the flow pipe higher than shown in fig. 880; or an accelerating motor may be used as described on page 219. The

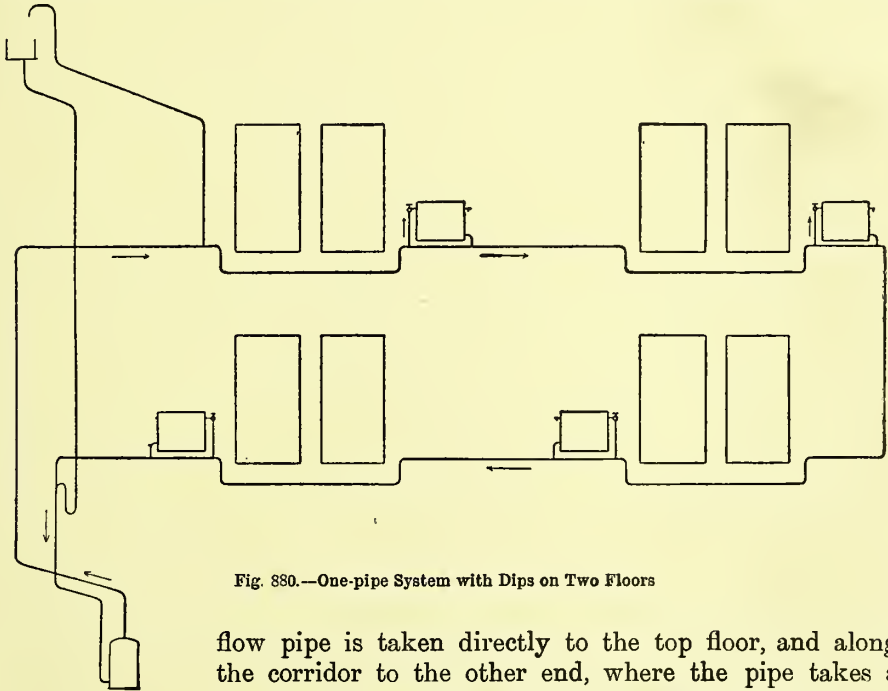


Fig. 880.—One-pipe System with Dips on Two Floors

flow pipe is taken directly to the top floor, and along the corridor to the other end, where the pipe takes a downward course to the corridor below; after the pipe has traversed that floor it descends and returns to the boiler.

The radiators can be arranged so that the main runs beneath them, but in that case the horizontal pipes would have very little fall. Only one air pipe is shown, as this would take away the greater portion of the air given off by the water; should any fail to escape by this pipe, it would be delivered into the radiators, and released when necessary.

Churches and chapels are often inadequately heated, the quantity of heating surface allowed being insufficient. Better results would be obtained if more radiators were fixed under windows and in other suitable positions. The warming of churches wholly by pipes of large size is not usually satisfactory; the pipes are unsightly, and the heating takes a long time. Churches are difficult to warm satisfactorily, if they are heated only once or twice a week during cold weather. The great area of exposed walls, windows, and roof surfaces rapidly cools the heated air that comes in contact with them, and precipitates it in the form of a draught upon

the heads of the occupants. To avoid down-draught from this cause, it is necessary to fix heating surfaces round the walls at the higher parts of the buildings, so that these cooling surfaces can also be warmed.

The practice of fixing pipes in channels covered with perforated iron grates is most objectionable, as the channels form receptacles for filth and for the germs of disease. The pipes also become covered with dirt and fluffy matter, which reduce their heating capacity. Pipes fixed in channels emit about 40 per cent less heat than similar pipes exposed to the free action of the air. Another disadvantage is the difficulty of effecting repairs without disturbing the sides of the channel, that is, when large pipes are used. Channels, however, cannot always be avoided in churches,

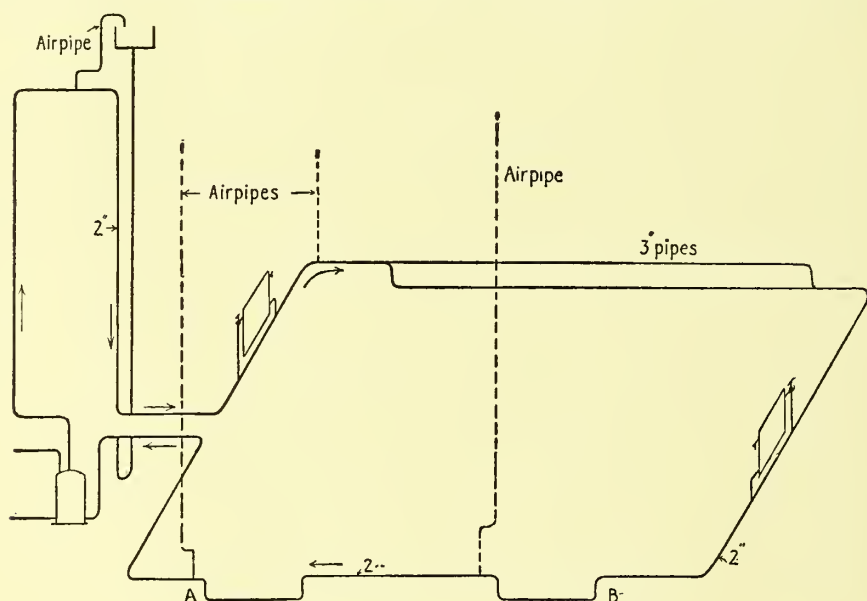


Fig. 881.—Heating Apparatus for a Small Church

as it is sometimes necessary for the main flow and return pipes to cross at least one of the aisles. In such cases the pipes should be wrapped with non-conducting material, and the channels should have solid covers.

A method of warming a small church, where the return pipes require to be dipped, is illustrated in fig. 881. In this case the heating surfaces are chiefly 3-in. cast-iron pipes and radiators. The stoke hole is shallow, and before the pipes can complete a circuit two dips are required, to cross passages at A and B. In order to make the water circulate through these dips, it is necessary to increase the head as shown. The 3-in. pipes are fixed a little above the floor and against external walls. One of the radiators is fixed near the door, in order to warm the air and prevent, as far as possible, a cold draught from that source; the other radiator is fixed under a window. The 2-in. pipe returns to the boiler along the floor, by the end of a row of seats near the centre of the building. Another circulation, with separate connections to the boiler, and

arranged precisely like the one shown, is supposed to warm the other side of the building. Air pipes are shown near the top of the bends where dips occur, to liberate any air that might tend to accumulate at these points. All the horizontal pipes, with the exception of the length between A and B, have a little pitch.

Ventilation.—A great number of churches and other public buildings depend entirely upon natural forces and automatic appliances for their ventilation, and when this is the case the heating and ventilation should be combined as far as possible. The system shown in fig. 881 can easily be arranged to aid the ventilation of the building by substituting ventilating wall radiators for the 3-in. pipes, and by providing fresh-air inlets to deliver the inflowing air against the radiators. The outlet ducts may be fixed in suitable positions in the roof.

The outlet ventilators should not unduly obstruct the flow of air through them, and must be effective in regard to weather conditions. Most outlet ventilators are subject to down-draught under certain conditions, or, if they really prevent it, it is also likely that they retard to a great extent the outflow of air. To minimize the ill effects of down-draught is not a very difficult matter in a building heated by steam, as a small coil can then be fixed at the base of each outlet ventilator. The heated coil will also rarefy the air in the upcast shaft, and accelerate the flow of air through it. A coil heated by low-pressure hot water would not be suitable, as there would be a difficulty in finding a suitable place for the supply cistern, and there would also be great danger of the water in the pipes being frozen in frosty weather.

Alternative System of Heating.—If a church or similar building is so constructed that its upper part cannot well be warmed by low-pressure hot water, other means of heating this part must be resorted to. If it is also intended to reduce the down-draught from outlet ventilators by fixing coils at their bases, low-pressure steam is the most satisfactory agent, and as it is not desirable to have two different systems for heating one building, the better plan is to heat the whole building by low-pressure steam. If steam were used for these buildings, its temperature could be more quickly raised, easily and quickly regulated, and the danger of an explosion through the water in the pipes being blocked by ice would be greatly reduced.

For warming large public buildings,¹ indirect heating is usually resorted to, as the ventilation of these places by natural or automatic means is not sufficiently reliable. The heating batteries are frequently heated by steam, but they may also be heated by either high- or low-pressure hot water.

Sizes of Pipes.—The sizes of pipes for supplying the necessary heat to the radiating surfaces will vary according to circumstances. Thus when long lengths of horizontal pipes are required, and the circulating head is small, the velocity of the circulation will be rather slow, and the pipes must be comparatively large. On the other hand, where a building is high, and only short lengths of horizontal pipes are necessary, the circulation will be quick, and smaller pipes may be used. It is clear, therefore, that in a table which gives the amount of heating surface that pipes of different

¹ See Section VII, chapter VII.

sizes will supply, the values will require modification to suit special conditions.

The diameter of pipes for supplying a given amount of heating surface, and the surface supplied by different sizes of pipes, can be determined from the following formulæ:—

For pipes less than 4 in. in diameter—

$$R = \sqrt{\frac{10 \cdot 25 d^5 h t^2 (W - w)}{l}} \quad . \quad . \quad (13)$$

$$d = \sqrt[5]{\frac{R^2 l}{10 \cdot 25 h t^2 (W - w)}} \quad . \quad . \quad (14)$$

For pipes 4 in. in diameter and over—

$$R = \sqrt{\frac{12 \cdot 8 d^5 h t^2 (W - w)}{l}} \quad . \quad . \quad (15)$$

$$d = \sqrt[5]{\frac{R^2 l}{12 \cdot 8 h t^2 (W - w)}} \quad . \quad . \quad (16)$$

- Where R = total heating surface in square feet.
 " d = diameter of pipe in inches.
 " l = length of pipe in circuit in feet, plus allowance for bends and other fittings.
 " t = difference between average temperatures in flow and return pipes respectively.
 " W and w = weight in grains of a cubic inch of water in return and flow pipes respectively.
 " h = circulating heads in inches.

Values of W and w are given in Table III, Chapter II.

Example 1.—How many square feet of radiating surface can be supplied by the arrangement shown in fig. 882? The circuit consists of 100 ft. of

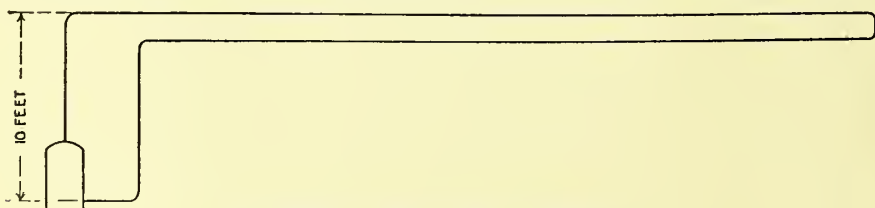


Fig. 882.—Diagram of Piping (Circulation Head, 10 ft.)

2-in. pipes, with a head of 10 ft.; average temperature of water in return 160° F., and 170° F. in flow pipe. By formula (13)—

$$\begin{aligned} R &= \sqrt{\frac{10 \cdot 25 \times 2^5 \times 120 \times 10^2 \times (247 \cdot 03 - 246 \cdot 19)}{100}} \\ &= \sqrt{\frac{10 \cdot 25 \times 32 \times 120 \times 100 \times \cdot 84}{100}} \end{aligned}$$

$\therefore R = 182$ sq. ft. of radiation.

This result is low, but the range of temperature through which the water is supposed to cool is also small.

Example 2.—In a circuit arranged like fig. 883, with 100 ft. of 2-in.

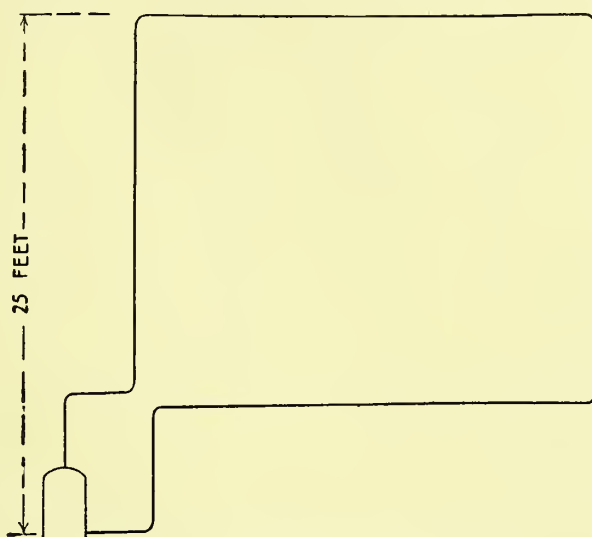


Fig. 883.—Diagram of Piping (Circulation Head, 25 ft.)

pipe, temperature of water in return pipe 160° F. and in flow pipe 175° F., circulating head 25 ft.—

$$R = \sqrt{\frac{10 \cdot 25 \times 2^5 \times 300 \times 15^2 \times (247 \cdot 03 - 245 \cdot 7)}{100}}$$

$$\therefore R = 542 \text{ sq. ft. of radiation.}$$

Example 3.—Find the diameter of a main to supply 2000 sq. ft. of radiation, when the temperatures in the flow and return pipes are 175° F. and 160° F. respectively. Assume a circuit similar to fig. 882, with 10 ft. of head, but consisting of 300 ft. of pipe. By formula (16)—

$$d = \sqrt[5]{\frac{2000^2 \times 300}{12 \cdot 8 \times 120 \times 15^2 \times (247 \cdot 03 - 245 \cdot 7)}}$$

$$\therefore d = 4 \cdot 8, \text{ (say) } 5 \text{ in. in diameter.}$$

Example 4.—Suppose a circuit is similar to fig. 883, with 25 ft. of head, but with the length of piping and temperatures as Example 3. Find the size of pipe to supply 2000 sq. ft. of radiation.

$$d = \sqrt[5]{\frac{2000^2 \times 300}{12 \cdot 8 \times 300 \times 15^2 \times (247 \cdot 03 - 245 \cdot 7)}}$$

$$\therefore d = 4 \text{ in. in diameter.}$$

TABLE XIII.—AMOUNT OF RADIATING SURFACE SUPPLIED BY PIPES OF DIFFERENT SIZE

Internal Diameter of Pipe.	Square Feet of Radiation. Chiefly Horizontal Pipes.	Square Feet of Radiation. Horizontal and Vertical Pipes.	Square Feet of Radiation. Vertical Pipes.
1 in.	40	50	75
1 $\frac{1}{4}$ "	75	90	130
1 $\frac{1}{2}$ "	130	150	250
2 "	230	360	600
2 $\frac{1}{2}$ "	360	500	800
3 "	520	650	1100
4 "	910	1280	2500
5 "	1600	2000	
6 "	2300	3460	
8 "	4600	6150	
10 "	8000	10,400	
12 "	11,520	14,000	
(1)	(2)	(3)	(4)

Air in Hot-water Apparatus.—The power which water possesses of dissolving nearly all gases depends largely upon its temperature and pressure.

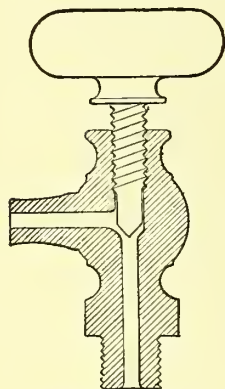


Fig. 884.—Air Cock

When water is heated, a portion of the air which it absorbed when cold is given off. If air were allowed to collect in hot-water pipes, the circulation of the water would, in some cases, be completely stopped; whilst in others an intermittent action would be caused, due to a portion of the confined air being occasionally expelled. As water is about 770 times as heavy as air, the latter tends to accumulate at the highest parts of the installation, and air outlets should therefore be provided at these points. A gradual rise given to the pipes facilitates the movement of the air to the highest points. When circulating pipes dip and rise, or *vice versa*, to pass a doorway, beam, &c., air outlets must be fixed at these points, so that air cannot be imprisoned.

Air Cocks, a simple pattern of which is shown in fig. 884, are largely used on radiators, coils, &c., and may be had with fast handles or loose keys. The cocks are occasionally opened by hand to allow the air to escape.

Air Pipes are preferable, if they can be conveniently used, as they require no attention, and are not likely to get out of order. These pipes should not be less than $\frac{3}{8}$ in. in diameter, as smaller pipes are easily choked.

Automatic Air Valves are sometimes used where air pipes cannot be conveniently fixed. Their chief disadvantage is the liability to get out of order, and, of course, if the valve does not properly close, through sticking or other defect, water leaks on to the floor.

Keith's Patent Aspirator Valve is of two kinds, one of which (No. 2, fig. 885) is arranged so that it will act as a stop cock, by simply turning

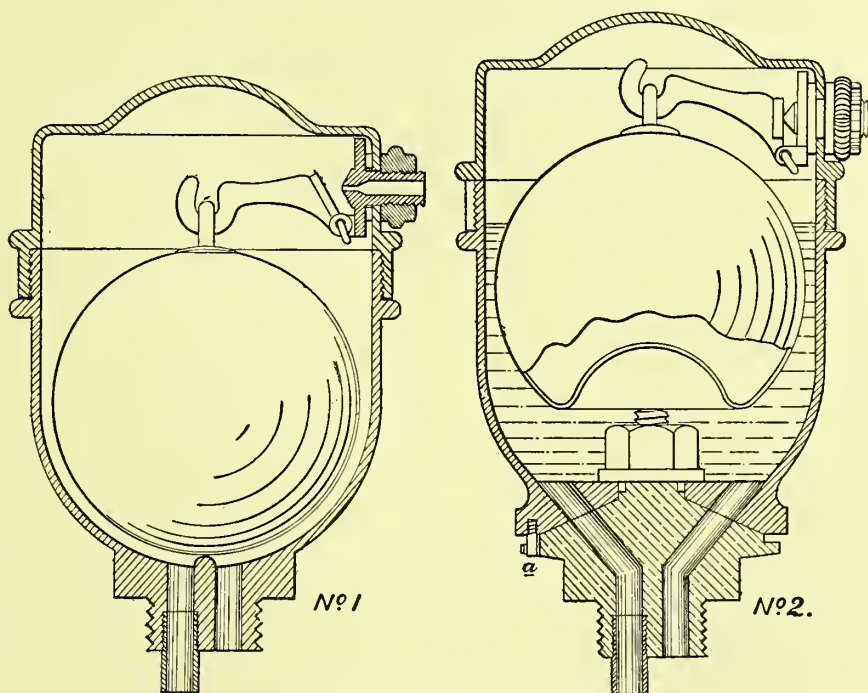


Fig. 885.—Keith's Patent Aspirator Valve

round the casing after the set screw *a* is removed. This allows the valve to be removed for repairs without turning off the water. The action of the valve is as follows. As air accumulates in the upper part of the chamber, the water is gradually displaced, and the ball falls by its own weight, thus opening the valve and allowing the confined air to escape, when the water again rises, lifts the ball, and closes the valve.

The "Ideal" Automatic Valve (fig. 886), made by the National Radiator Company, is similar in principle, but has a threaded spindle valve *A*, which can be used to shut off the water while the air valve is being examined.

Valves or Stop Cocks.—The valves or stop cocks fixed on pipes and radiators should be of such construction as not to

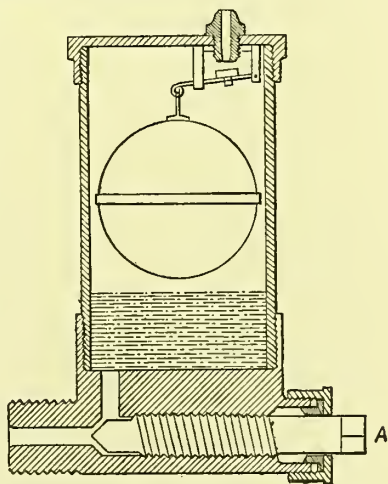


Fig. 886.—The "Ideal" Automatic Air Valve

retard unduly the flow of water through them. For this reason the globe valve (fig. 887), which is similar in construction to an ordinary high-

pressure cock, is not well adapted for heating work. The water twice changes its direction in flowing through it, and the water passages are often very contracted. When the globe valve is fixed on horizontal pipes with its spindle upwards, air accumulates on one side of it, but this trouble can be overcome by fixing the valve on its side. Its chief advantage is its cheapness. A more suitable type for horizontal pipes is Peet's gate valve (fig. 888), which, when open wide, gives a clear way and offers little resistance to the flow of water.

Radiator Valves are often of an angle pattern (fig. 889), as this type allows of a neat connection being made. They can be obtained with or without union connections, but the unions facilitate the work of connecting to the radiator. With the valve

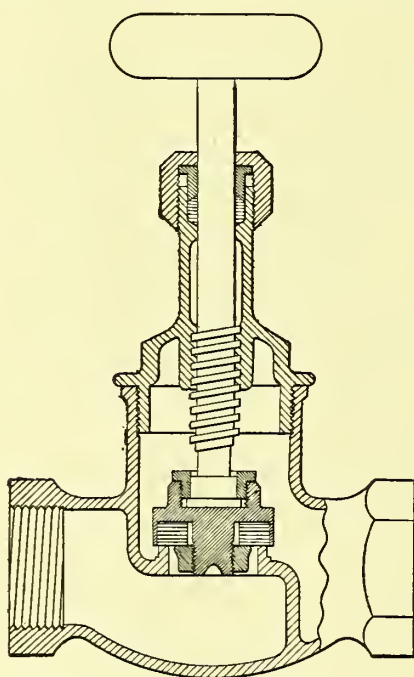


Fig. 887.—Globe Screw-down Valve

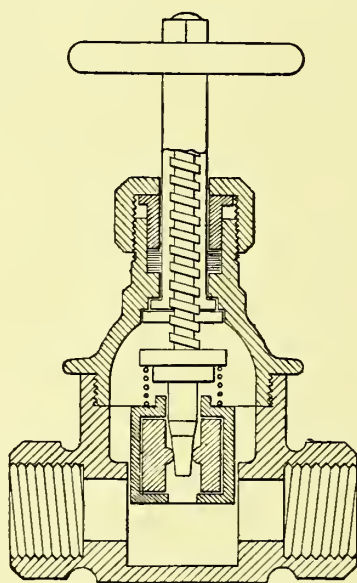


Fig. 888.—Peet's Gate Valve

shown in fig. 889 the spindle requires to be turned a number of times before it is wide open. A quick-action valve is shown in fig. 890. If the connections to a radiator are such that neither angle nor straight valves can be conveniently used, corner valves can be obtained for both right- and left-hand positions.

A hot-water apparatus should be provided with a **draw-off cock** near the return connection to the boiler, so that the installation can be emptied of water when desired. If the supply cistern is not fed with a constant supply, the draw-off cock should have a loose key. If the boiler is in an undrained basement, a second draw-off cock may be fixed at a higher level, so that as much water as possible can be discharged into a drain gully.

The size of the supply cistern should be proportionate to the volume of water contained in the heating system, and should be sufficient to hold the

increased bulk of water which is displaced from the heating system when the water is raised to its highest temperature. 1000 gal. of water, when heated from 46° F. to 212° F., become 1044 gal., so that water, upon being raised through this range of temperature, expands nearly $\frac{1}{3}$ rd of its original bulk. When the capacity of a cistern to hold the water displaced from the apparatus by expansion is calculated, the height of the water at which the ball cock closes should be added to the depth of the cistern. It is not likely that the whole of the water in the apparatus will be raised to anything like 212° F., but the extra accommodation provided by calculating to 212° F. is advisable.

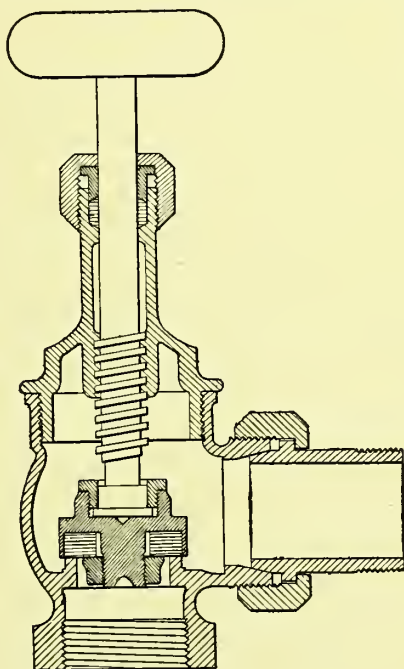


Fig. 889.—Angle Valve with Union

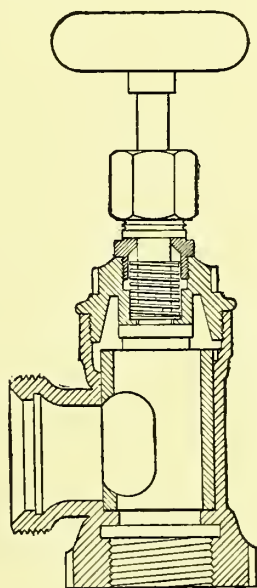


Fig. 890.—Quick-action Angle Valve

The quantity of water in gallons held by various sizes of pipes can be found by the following rule:— $G = \frac{d^2}{144} \times .7854 \times 6.23 \times l$; or more simply—

$$G = d^2 \times .034 \times l \quad . \quad . \quad . \quad . \quad (17)$$

Where G = volume in gallons.

„ d = diameter of pipe in inches.

„ l = length of pipe in feet.

Example.—If a system is composed of 1000 ft. of 4-in. pipes, 500 ft. of 3-in. pipes, and 200 ft. of 2-in. pipes, find its total capacity.

The 4-in. pipes hold $4 \times 4 \times .034 \times 1000 = 544$ gal.

„ 3-in. „ $3 \times 3 \times .034 \times 500 = 153$ „

„ 2-in. „ $2 \times 2 \times .034 \times 200 = 27.2$ „

$\therefore$ total capacity = 724.2 „

The required provision for expansion equals the contents in gallons divided by 23. $\therefore 724.2 \div 23 = 31.48$, or (say) $31\frac{1}{2}$ gal. As there are approximately $6\frac{1}{4}$ gal. in a cubic foot, the space to be provided for expansion will be $31\frac{1}{2} \div 6\frac{1}{4} = 5$ cu. ft. Assuming the cistern to be 2 ft. 6 in. long and 1 ft. 6 in. wide, the depth to hold $31\frac{1}{2}$ gal. = $\frac{31\frac{1}{2}}{2\frac{1}{2} \times 1\frac{1}{2} \times 6\frac{1}{4}} = 1$ ft. 4 in.

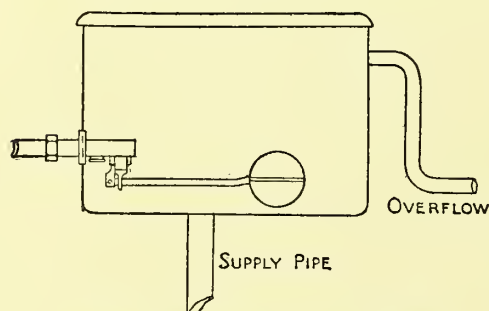


Fig. 891.—Cistern with Ball Cock and Overflow

If the ball cock closes with 4 in. of water in the cistern, the depth of the cistern below the overflow must be 1 ft. 4 in. + 4 in. = 1 ft. 8 in.

Cistern Fittings.—The overflow pipe (fig. 891) is necessary to take away the water in case the ball cock is out of order at any time. The ball cock is fixed near the bottom of the cistern, and regulated to close when the

cistern contains a few inches of water, thus leaving the upper portion to accommodate the expanded water. If the cistern is fixed in a conspicuous place, the pipes can be more neatly arranged by making all the connections at the bottom. In a small heating apparatus the water supply is not always connected with the cistern, but water is added from time to time by the attendant.

Feed Pipes.—The pipe from the cistern to the apparatus serves for supply and expansion, and should not be less than 1 in. in diameter. It may be connected to the boiler or to any convenient return main. There is no special advantage in connecting it to the boiler unless the cistern is near this. A good method of connecting it to the apparatus is shown in No. 1, fig. 892, the supply being simply dipped below the level of the return pipe to which it is joined. No. 2 illustrates another method which is occasionally adopted, but it is not a good one, as trouble may be caused, when charging the apparatus, by confined air between the two traps.

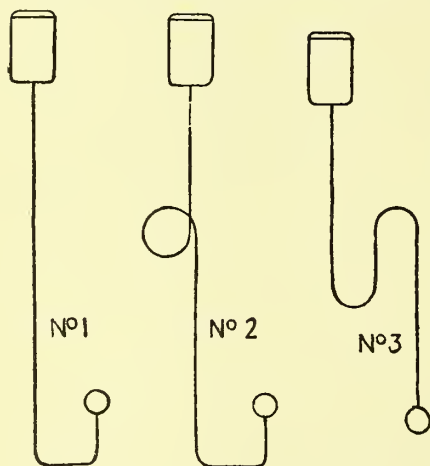


Fig. 892.—Three Methods of Connecting the Feed Pipe to the Apparatus

When it is not convenient to connect the supply to the bottom of a pipe, it may be joined at the top by arranging it as shown in No. 3.

Dips or traps in feed pipes are introduced to prevent the water from circulating back into the supply cistern, instead of circulating through the heating pipes. The resistance offered by the dip must, then, be greater than that due to the friction which is encountered by the water when

circulating through the pipes. Hot water is sometimes displaced from a heating apparatus by overfiring, more especially when the system has a very sluggish circulation.

The height of the supply cistern need not be more than 2 ft. above the highest part of the heating surfaces, but in practice the cistern is often placed in the most convenient position. The height should in no case be much greater than that actually required, for excessive heads only put extra pressure and strain upon the apparatus without the slightest advantage to the circulation.

CHAPTER VIII

LOW-PRESSURE HOT-WATER APPARATUS: HORTICULTURAL WORK

Pipes and Radiators.—Horticultural buildings require to be maintained during the night at temperatures which approach uniformity. The circulating head is usually small, but the slowness of the circulation, due to this and to the long horizontal pipes, is compensated to a certain extent by the size of the pipes, which are often 4 in. and seldom less than 3 in. Radiators are not suitable, as they hold only a small volume of water, and would allow the temperature to fluctuate readily.

Position of Boiler.—When arranging a system to heat a number of greenhouses, the boiler or boilers should be fixed nearest those which require the greatest amount of heat, such as propagating and forcing houses. Greenhouses and those which require the least heat should be situated at the greatest distance from the boilers. Great waste of fuel would otherwise result, as the fires would require forcing in order to deliver water at a high temperature in the more distant pipes. Under ordinary conditions the water in travelling through the pipes would be cooled considerably, and additional piping would be required to raise a distant building to a high temperature.

When a number of buildings are heated, it is usually advisable to provide not less than two boilers, so that the firing can be better regulated to suit the positions and temperatures of the buildings, and also so that if one boiler breaks down the other can be used to keep the houses at a temperature sufficiently high to preserve the plants.

The pipes are fixed within beds or exposed to the air of the building according to the kind of heat required. When heat is diffused within or under the beds, it is commonly termed "bottom" heat; and when direct radiation is used, it is termed "top" heat.

The heating surfaces for horticultural work should always be very liberal, so that the required temperature in the building can be easily maintained without raising the water in the pipes to a very high temperature.

Top Heat.—Exposed pipes are fixed mainly in the lowest part of the building, and are kept clear of the floor to prevent loss of heat by conduction. In order to avoid dipping beneath doorways, when a door is provided at each end of a building, a separate circuit for each side should

be provided. If three pipes are required for one circuit, the flow may consist of two pipes, the third pipe being the return.

In addition to the pipes near the floor, it is sometimes desirable, especially in palm and similar houses, to fix a 2-in. wrought-iron pipe along the

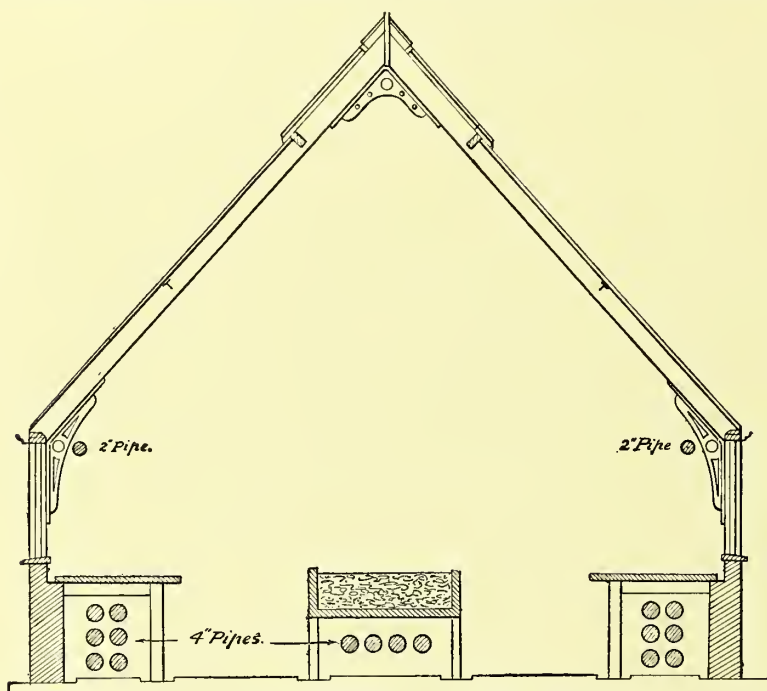


Fig. 893.—Transverse Section of Palm House

eaves to protect the plants from the cold when their leaves come near the glass surfaces. With long lean-to roofs a 2-in. pipe might be fixed along the centre, and another along the eaves. Pipes cannot be fixed in the roofs, of course, unless the feed cisterns are at a higher level.

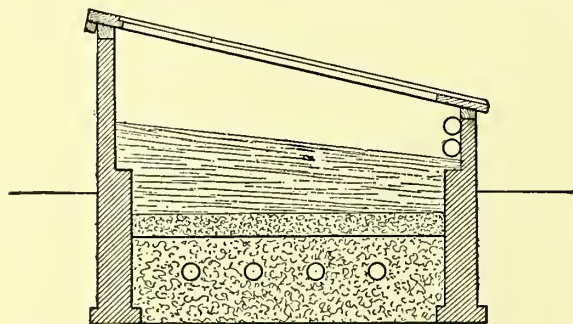


Fig. 894.—Cucumber Pit

A large palm house is shown in fig. 893 with six lengths of 4-in. pipe on each side, and one 2-in. pipe at each eave. The centre bed is provided with bottom heat. The pipes on each side of the building form separate circuits, and the pipes in the centre

bed may be arranged to form either one or two circuits, so that the degree of heat can be regulated as desired. Sufficient piping should be allowed in order that the gardener may adjust the bottom heat to suit different plants.

To obtain bottom heat a common method is that of fixing pipes underneath perforated iron grates or corrugated iron sheets, upon which the soil or mould is placed, as shown in fig. 893. This kind of heat is utilized only for warming the soil, and is not taken into account when ascertaining the

heating surface for top heat. In the cucumber pit, shown in fig. 894, the bottom heat is provided by hot-water pipes, which are surrounded with coarse rubble,

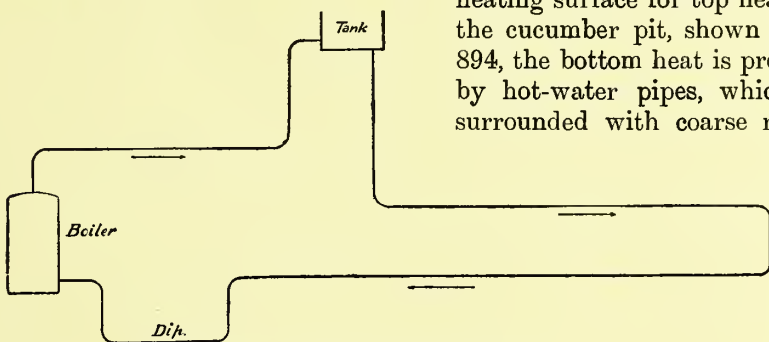


Fig. 895.—Apparatus with Dip in Return Pipe

and on this the soil is placed. Top heat is obtained by the upper pipes fixed in the position shown.

Dips or traps should be avoided as far as possible, as the head for circulation is usually small; and if even one dip is made, the rate of

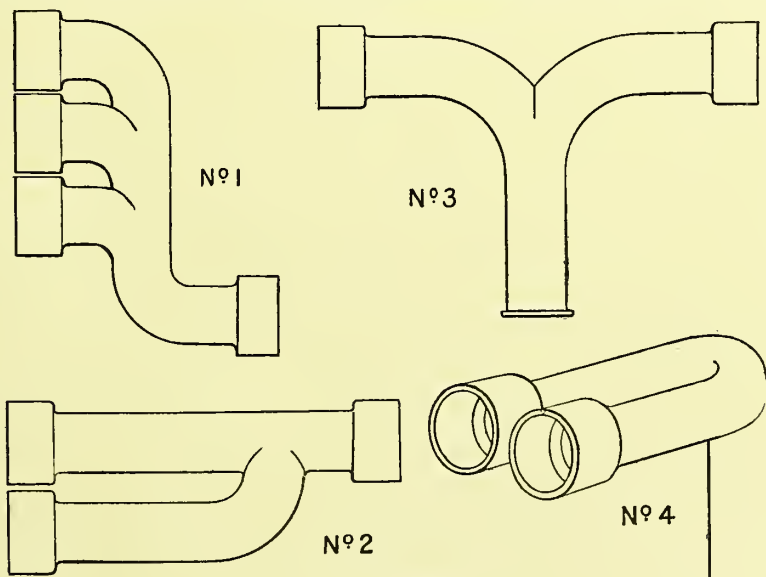


Fig. 896.—Branch Pieces

circulation is much reduced. In ordinary buildings obstacles are comparatively easy to overcome by simply increasing the circulating head, but the extent to which this can be increased in horticultural buildings is usually very limited. Fig. 895 shows a method of piping which can be adopted for overcoming unavoidable dips. The flow pipe is connected to

an open tank, which also serves as the feed cistern; from this tank a return pipe is taken to the level desired, and returned to the boiler.

Branch pieces (fig. 896) and other castings are made in forms to suit almost any conceivable position and requirement.

Throttle valves (fig. 897) are largely used for horticultural work, and can be partly closed to check the circulation in any section of a system. If valves are fixed on the flow and the return pipes, the circulation can be stopped. Throttle valves, however, do not shut off tightly. When tight-fitting valves are required, those selected should have clear passages through them when wide open, such as Peet's valve (fig. 888).

Evaporating troughs (fig. 898) are often fixed on hot-water pipes, so that they can be filled with water to moisten the air. A great amount of moisture is necessary for plants that are cultivated in high temperatures. These troughs are either cast on the pipes, or made independently and fixed on the pipes where required.

The boilers principally used for horticultural work are the "Saddle" (fig. 856), "Terminal end" (figs. 857 and 858), "Trentham" (fig. 860), and

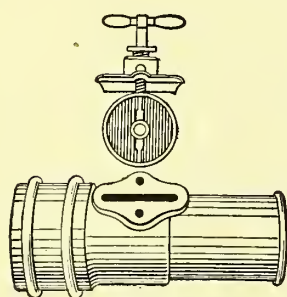


Fig. 897.—Throttle Valve

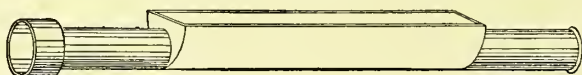


Fig. 898.—Evaporating Trough

independent cast-iron sectional types (figs. 865 to 868). For small greenhouses independent boilers, such as the "Finsbury" (fig. 861), are often used.

Span and Lean-to Houses.—Span-roofed houses are considered better for cultural purposes than lean-to, as the former receive more light; but lean-to houses are more easily warmed, as they are less exposed to the wind and weather.

The amount of heating surface will depend upon the internal temperature required, temperature of external air, size of building, amount of cooling surface, and situation; but it must be sufficient to maintain a given temperature throughout the night, when the outside temperature is at its lowest and when the firing receives little or no attention.

TABLE XIV.—AVERAGE NIGHT TEMPERATURES FOR HORTICULTURAL BUILDINGS

Kind of Building.	Temperature required, F.
Cool houses to keep out frost	45°
Greenhouses and Ferneries	50°
Houses for Peaches, Cucumbers, Vines, Tomatoes	55°
Houses for Orchids and Exotic Ferns	60°
Stoves and Pineapple and Melon Pits	65°
Propagating Houses and Tropical Plants	70°
Forcing Houses	75°-80°

The heating surfaces can be calculated in a similar way to those required for ordinary buildings, but the glass value will be a little less. Glass in greenhouse work may be considered to absorb 1 unit of heat per degree difference of temperature per hour for each square foot of surface. The heat absorbed by walls will be the same as for other buildings. The number of times the air of horticultural buildings is changed per hour must necessarily depend upon the size of the building and of the apertures for ventilation and the exposure to winds, &c.; for purposes of calculation the number of air changes per hour may be assumed to be 3 in buildings containing less than 1500 cu. ft., $2\frac{1}{2}$ in buildings containing between 2000 and 3000 cu. ft., 2 in buildings containing between 4000 and 5000 cu. ft., and $1\frac{1}{2}$ in larger buildings.

Let u = amount of heat emitted per lineal foot of 4-inch pipe per degree difference in temperature per hour.

„ P = temperature of water in pipes.

„ T = temperature of building.

„ t = temperature of external air.

„ n = number of times the air of building is changed per hour.

„ C = capacity of building in cubic feet.

„ W = area of exposed wall surface in square feet.

„ G = area of glass in square feet.

„ L_1 = length of 4-in. pipe required for ventilation.

„ L_2 = length of 4-in. pipe required for exposed walls.

„ L_3 = length of 4-in. pipe required for glass.

„ L = total length of 4-in. pipe required.

$$\text{Then, } L_1 = \frac{.021 C n (T - t)}{u(P - T)}, \quad L_2 = \frac{.4 W (T - t)}{u(P - T)}, \quad L_3 = \frac{G (T - t)}{u(P - T)}.$$

$$\therefore L = \{.021 C n + .4 W + G\} \left\{ \frac{T - t}{u(P - T)} \right\} \quad (18)$$

Where $P - T = 110$, the value of $u = 1.8$.

„ $P - T = 100$, the value of $u = 1.7$.

„ $P - T = 90$, the value of $u = 1.6$.

If some of the values are now substituted, the formula can be simplified. Thus, taking $P = 170^\circ$, $T = 60^\circ$, and $t = 30^\circ$ —

$$L = (.021 C n + .4 W + G) \times .1515$$

Multiplying each value within the brackets by .1515 and obtaining its reciprocal, the following simple rule is obtained, but of course this applies only to the temperatures stated:—

$$L = \frac{C n}{310} + \frac{W}{16} + \frac{G}{6.6} \quad (18a)$$

Where $P = 160^\circ$, $T = 60^\circ$, and $t = 30^\circ$, the simplified formula becomes—

$$L = \frac{C n}{270} + \frac{W}{14} + \frac{G}{5.6} \quad (18b)$$

And where $P = 150^{\circ} \text{ F.}$, $T = 60^{\circ} \text{ F.}$, and $t = 30^{\circ} \text{ F.}$ —

$$L = \frac{Cn}{230} + \frac{W}{12} + \frac{G}{5} \quad . \quad . \quad . \quad . \quad . \quad . \quad (18c)$$

Example.—Find the length of 4-in. pipe required for warming a greenhouse to 60° F. when the outside air is at 30° F. , and the water in the pipes is at 170° F. Capacity of building 6300 cu. ft., area of exposed wall 256 sq. ft., and 1200 sq. ft. of glass.

To calculate this, formula (18a) will be required.

The air changes for 6300 cu. ft. will be, as stated above, one and a half times per hour.

$$\begin{aligned} L &= \frac{Cn}{310} + \frac{W}{16} + \frac{G}{6.6} = \frac{6300 \times 1\frac{1}{2}}{310} + \frac{256}{16} + \frac{1200}{6.6} \\ &= 30.5 + 16 + 181.8 = 228 \text{ ft. of 4-in. pipe.} \end{aligned}$$

Assuming the temperature of the water in the pipes to be only 150° F. , and the other particulars as before, we should find that 302 ft. of 4-in. pipe would be required.

Formulas (18a), (18b), and (18c) are limited in their application, as shown. In order to make them applicable for a wide range of temperatures, a table of coefficients which has been calculated by Mr. W. Jones is given. These coefficients do not appear so reliable for horticultural buildings which have a capacity exceeding 6000 cu. ft. as for smaller buildings.

TABLE XV.—COEFFICIENTS FOR VARYING TEMPERATURES IN HORTICULTURAL BUILDINGS

Internal Tempera- tures, F.	External Temperatures, F.													
	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	
40°	1.128	.988	.845	.705	.562	.422	.283	.14						
45°	1.32	1.17	1.03	.88	.735	.588	.441	.294	.147					
50°	1.53	1.378	1.224	1.07	.919	.764	.61	.459	.305	.15				
55°	1.75	1.59	1.43	1.27	1.11	.955	.797	.636	.477	.32	.158			
60°	1.98	1.83	1.66	1.5	1.33	1.16	1	.834	.665	.5	.33	.165		
65°	2.27	2.1	1.92	1.75	1.57	1.4	1.22	1.01	.875	.7	.52	.349	.172	
70°	2.57	2.39	2.2	2.02	1.83	1.65	1.47	1.28	1.1	.919	.735	.551	.367	
75°	2.9	2.7	2.51	2.32	2.12	1.93	1.73	1.54	1.35	1.15	.966	.772	.677	
80°	3.26	3.06	2.85	2.65	2.44	2.24	2.04	1.8	1.63	1.42	1.22	1.01	.816	

Example.—A building of 1500 cu. ft. capacity, with 250 ft. of exposed wall surface and 580 ft. of glass, requires to be maintained at 75° F. when the external air is at 35° F. , the average temperature of the water in the pipes being 160° F. , and the air being changed three times per hour.

First find the length of 4-in. pipe required for 60° F. inside and 30° F. outside by formula (18b)—

Then $L = \frac{1500 \times 3}{270} + \frac{250}{14} + \frac{580}{5.6} = 138 \text{ ft. of 4-in. pipe for internal and external temperatures of } 60^{\circ} \text{ F. and } 30^{\circ} \text{ F. respectively.}$

From Table XV the coefficient for an inside temperature of 75° F. and outside temperature of 35° F. is 1.54.

$\therefore 138 \times 1.54 = 212\frac{1}{2}$ ft. of 4-in. pipe required.

A table is also included which gives the approximate quantities of heating surfaces for different sizes of horticultural buildings. The amount of heating surface cannot be accurately ascertained from the cubic capacity of a building alone, as the amount of heating surface per 1000 cu. ft. of space varies considerably with the size and kind of structure. For example, a long low building will sometimes require 90 ft. of 4-in. pipe per 1000 cu. ft. to maintain a temperature of 60° F., while a building of larger dimensions could be kept at the same temperature by 38 ft. run of 4-in. pipe per 1000 cu. ft. of space.

TABLE XVI

Temperature required, F.	Total Capacity of Building 2000 cu. ft. approximately.	Total Capacity of Building 6000 cu. ft. approximately.
	Length of 4-in. Pipe per 1000 cu. ft.	Length of 4-in. Pipe per 1000 cu. ft.
40°	16	12
45°	24	18
50°	33	24
55°	43	32
60°	54	40
65°	66	49
70°	79	59
75°	93	70
80°	110	82
85°	128	93

CHAPTER IX

HIGH-PRESSURE AND MEDIUM-PRESSURE HOT-WATER APPARATUS

The low-pressure hot-water heating apparatus is subjected only to a pressure equivalent to the head of water in the cistern which supplies it, and as the cistern is open to the atmosphere, the increase of the water temperature cannot affect the pressure, unless the pipes are blocked.

The high-pressure apparatus, invented by Perkins in 1831, is hermetically sealed, and the pressure depends not only upon the head of water but also upon the temperature to which the water is raised. It consists of lap-welded wrought-iron tubes screwed together with left- and right-hand threaded joints, the boiler often being formed of similar tubes coiled into any suitable shape. The tubes or pipes are of $\frac{7}{8}$ -in. bore, and tested (before

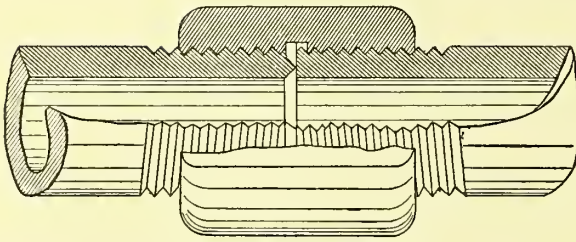


Fig. 899.—High-pressure Pipe Joint

leaving the works) to a pressure of over 3000 lb. per square inch. After fixing, the whole apparatus is tested by hydraulic pressure to about 2000 lb. per square inch.

The tubes weigh approximately $2\frac{3}{4}$ lb. per lineal foot, and are

screwed with right- and left-hand threads, and fitted with strong chambered sockets. There are fifteen threads to the inch, the pitch being finer than that used for steam or gas pipes. The joints are made secure by

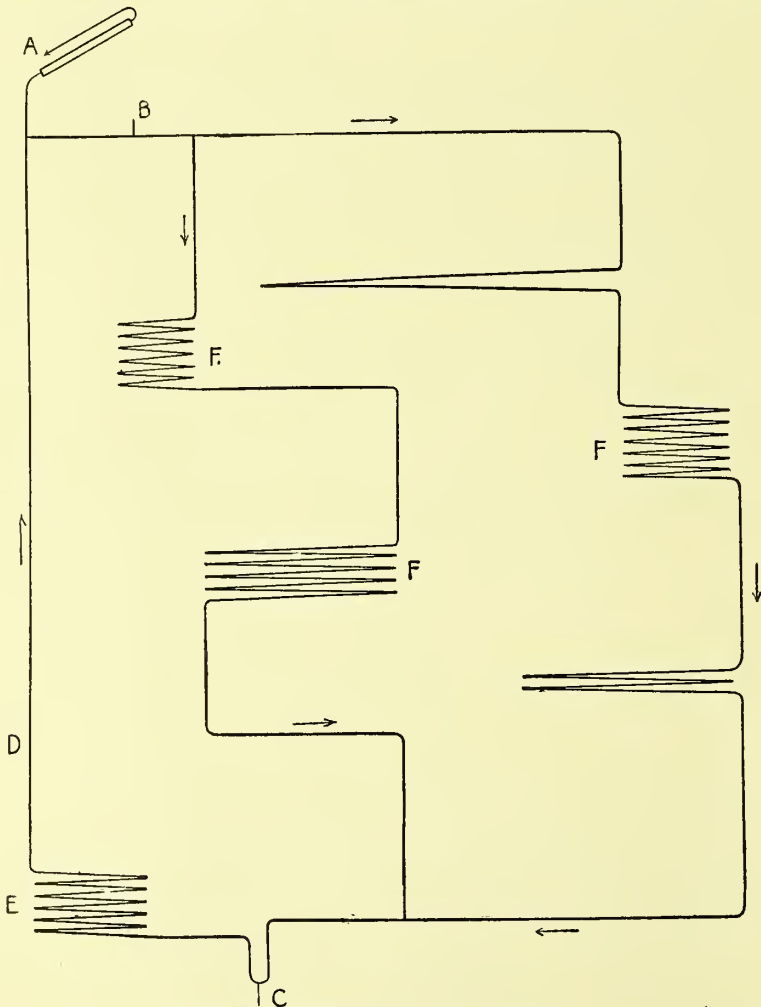


Fig. 900.—High-pressure Hot-water Apparatus

A, Expansion pipe and plug; B, Recharging plug; C, Filling plug; D, Flow pipe; E, Boiler; FFF, Coils.

metallic contact, the coned end of one pipe being forced on to the flat-faced end of the next (fig. 899). No jointing material of any description is required.

In order to provide space for the expansion of the water when heated, an expansion tube is connected at the head of the system. It is made in varying lengths and sizes to suit different sizes of installation.

An arrangement of piping is shown in fig. 900. A coil of pipe E, fixed within a furnace, forms the boiler; the flow pipe D rises to the highest point, where the expansion tube A is provided. The apparatus is charged with water at C by means of a force pump. B denotes the point for adding water periodically as required. The plug at A is removed when adding water at B. The quantity of water contained in the pipes is very small, hence the water is quickly heated after the fire is lighted. As the pipes are small, they can be fixed in places where it would not be possible to run large pipes. For heating buildings the pipes are fixed around the walls, either along the front of skirting boards (fig. 901, No. 1) or behind gratings (No. 2), or in floor channels (No. 3).

The pipes must be fixed 3 in. clear of woodwork and other inflammable material in order to conform to the provisions of the Building Acts. When the pipes require to pass through floors and ceilings, they are often slipped through larger pipes to keep them clear of combustible material.

Coils (FF, fig. 900) are often used when a large amount of heating surface requires to be concentrated in a confined area; in halls or other important positions they can be concealed by ornamental cases.

Air cocks are not used, as the air is dislodged from the pipes as far as possible when the apparatus is first charged with water. Air given out during the heating of the water will collect in the expansion tube if the pipes are properly arranged.

Dips.—As the circulation is very rapid, the pipes can be dipped beneath doorways, passages, &c., if proper care is observed. The pipes, however, require arranging so that the water will circulate in the proper direction; this can be accomplished by taking the flow pipe by the most direct route

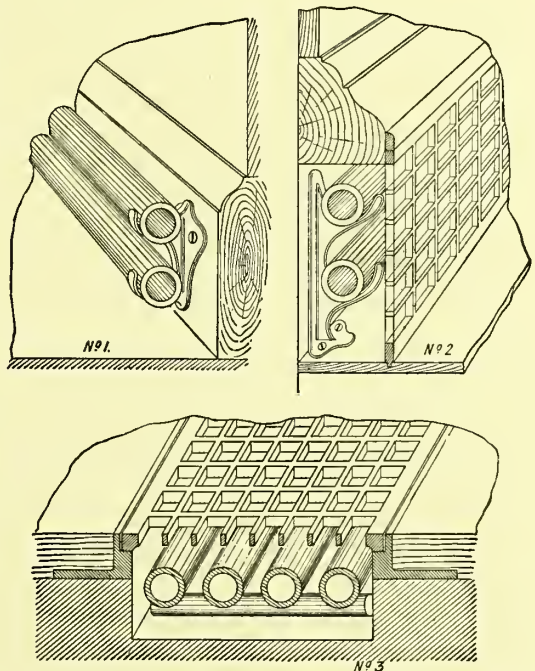


Fig. 901.—Three Methods of Running the Pipes

to the highest point, and making a dip on the return just before it joins the boiler coil as shown at c, fig. 900.

Objections to the System.—The high-pressure system of heating is not one that generally finds favour. The term high pressure is in itself prejudicial to the common adoption of the system, and certain failures (chiefly due to bad design) and the number of explosions that have taken place with this apparatus have done much to bring it into disfavour. The high temperature of the pipes overheats the air and renders a room stuffy, and another common failing is the unequal distribution of heat, the higher rooms of a building being too hot, while those on the ground and basement floors are insufficiently heated. In such a case the system itself is not altogether to blame, but the chief responsibility rests with the engineer who designed the apparatus, for not proportioning it properly. The temperature of the water in the return is very much lower than that in the flow, if there is a long length of piping, and consequently the heating surfaces formed by returns near the boiler may require to be from two to three times greater than those at the head of the circuit to emit equal amounts of heat.

The temperature to which the water in the apparatus is raised for ordinary work is about 300° F., but may be considerably higher. These high temperatures show the necessity for providing sufficient room to accommodate the increased volume of water. The force of expanding water is practically irresistible, and if too small a space is provided an explosion must take place when the critical temperature is reached.

The expansion of water is not equal for each degree rise of temperature, but increases as the temperature of the water is increased. The following table gives the approximate expansion of water upon being heated from 40° F. to 600° F.:—

TABLE XVII.—EXPANSION OF WATER

Temperature, Degrees F.	Volume.	Rate of Expansion from 40° F. Approx.	Temperature, Degrees F.	Volume.	Rate of Expansion from 40° F. Approx.
40	1	—	400	1·1484	$\frac{1}{6}$ its volume
212	1·0433	$\frac{1}{23}$ its volume	450	1·1843	$\frac{1}{5}$ „ „
300	1·0869	$\frac{1}{11}$ „ „	500	1·2233	$\frac{1}{4}$ „ „
350	1·1156	$\frac{1}{8}$ „ „	600	1·3099	$\frac{1}{3}$ „ „

The size of the expansion tube can be determined when the total length of piping in the installation is known. The capacity of the expansion tube must be sufficient to accommodate the increased bulk of water, plus an allowance for confined air and a margin of safety. 1 gal. of water is contained in 44·53 ft. run of $\frac{7}{8}$ -in. pipe; the tube is really $\frac{1}{8}$ -in. bore, and its capacity in gallons can be ascertained by dividing the total length of piping by 44. Thus, the volume of water contained in 1760 ft. of pipe will be $1760 \div 44 = 40$ gallons. If the temperature is raised from 40° F. to 350° F., the volume of the water will, according to Table XVII, be increased approximately by one-eighth, or in this case by 5 gallons.

The length and diameter of an expansion tube can be found by the aid of the following formulæ:—

$$l = \frac{G}{d^2 \times .034} \quad . \quad . \quad . \quad . \quad (19)$$

$$d = \sqrt{\frac{G}{l \times .034}} \quad . \quad . \quad . \quad . \quad (20)$$

Where l = length in feet of expansion tube filled with the expanded water.

„ d = internal diameter of expansion tube in inches.

„ G = capacity of installation in gallons.

Example 1.—Find the length of tube 4 in. in diameter that will just accommodate 5 gal. of water.

$$l = \frac{G}{d^2 \times .034} = \frac{5}{4^2 \times .034} = 9.19 \text{ ft.}$$

Example 2.—Find the diameter of a tube 10 ft. in length to hold 4 gal. of water.

$$d = \sqrt{\frac{G}{l \times .034}} = \sqrt{\frac{4}{10 \times .034}} = \sqrt{11.77} = 3.43 \text{ or (say) } 3\frac{1}{2} \text{ in.}$$

The length found by formula (19) does not include the space required for imprisoned air or the necessary margin of safety, and for these must be added—(say) one-fifth of the length found by the rule, or in the first example about 2 ft. Conversely, when it is required to find the diameter of an expansion tube, a deduction of one-sixth must be made from the given length. The length from which the diameter of the tube in Example 2 would be calculated is therefore $10 - \frac{10}{6} = 8\frac{1}{3}$ ft. According to Boyle's

Law the volume of a gas is inversely proportional to its pressure, but this law cannot be applied to determine the pressure in the expansion tube, although it is useful in determining the size.

Upon heating up an installation the pressure is found to fluctuate considerably with varying temperatures, and not to follow any recognized law. This erratic action is no doubt chiefly due to friction encountered by the water in its passage through the pipes and to the generation of steam.

Tests by Mr. Walter Jones.—Two very interesting and instructive tests by Mr. Walter Jones¹ were made on a small apparatus with a column of mercury in contact with the flow pipe, and the glass bulb of a thermometer immersed in the mercury. Test I, in which the temperature was raised from 200° F. to 500° F., extended over a period of one hour, and showed an increase of pressure from 25 lb. per sq. in. at 200° F. to 1300 lb. at 500° F. Test II, in which the temperature ranged from 50° F. to 270° F., was continued half an hour, during which the pressure increased from 0 to 100 lb. per sq. in.

In Test I three different pressures, ranging from 525 to 1000 lb., were recorded when the temperature in the flow pipe was 400° F., and when the

¹ *Heating by Hot Water, Ventilation, and Hot-water Supply.*

temperature was raised to 430° F. the pressure dropped to 725 lb. per square inch. In Test II similar eccentricities were observed. The wide fluctuations appear to have been chiefly due to the generation of steam and its condensation, which were probably caused by temporary stoppages of the circulation owing to the accumulation of air in dips or pockets. If a partial stoppage of the circulation took place owing to lodgment of air, the temperature of the water in the flow would gradually increase and generate steam until the pressure was sufficiently great to dislodge the air; upon the circulation again being free the greater portion of the generated steam would be condensed and the pressure would fall accordingly. These tests clearly show that dips in a small-bore apparatus should be avoided as

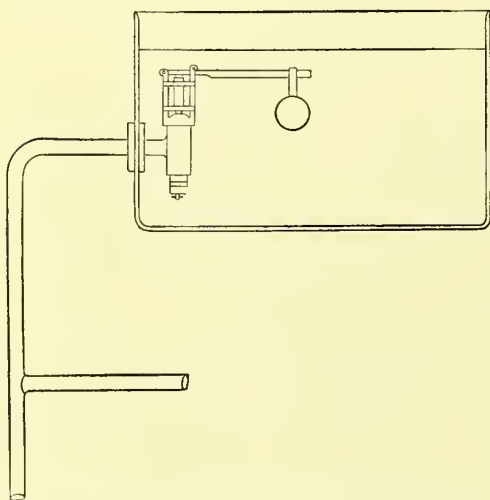


Fig. 902.—Tank for Medium-pressure Hot-water Apparatus

far as possible, and that the pipes should be arranged so that the circulation will not be unduly retarded.

Wide fluctuations of pressure must decrease the life of an apparatus, owing to the unequal straining to which it is subjected. It must also be

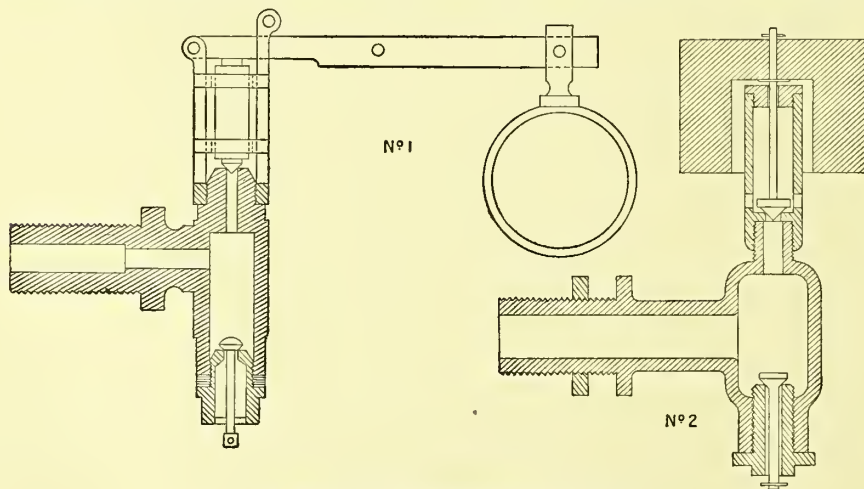


Fig. 903.—Valves for Medium-pressure Apparatus

remembered that the cohesive strength of metals is reduced with increase of temperature, and although a tube when cold may withstand a pressure exceeding 5000 lb. per square inch, it may not be capable of doing so when it is raised to a very high temperature.

The medium-pressure system is superior to the high-pressure system for warming buildings, such as private houses, where very high temperatures are not required. The only difference between the two systems is the substitution of a tank and valve (fig. 902) in the medium pressure for the expansion tube in the high-pressure system. In the medium-pressure system, with a properly constructed valve, the water can be raised only to a limited temperature or pressure, and if that is exceeded water passes out from the apparatus into the cistern through the valve. This valve also permits water to return into the system when it begins to cool down.

Two forms of valve, for fixing in the supply cistern, are illustrated in fig. 903, and serve the purpose of pressure-relief and vacuum valves.

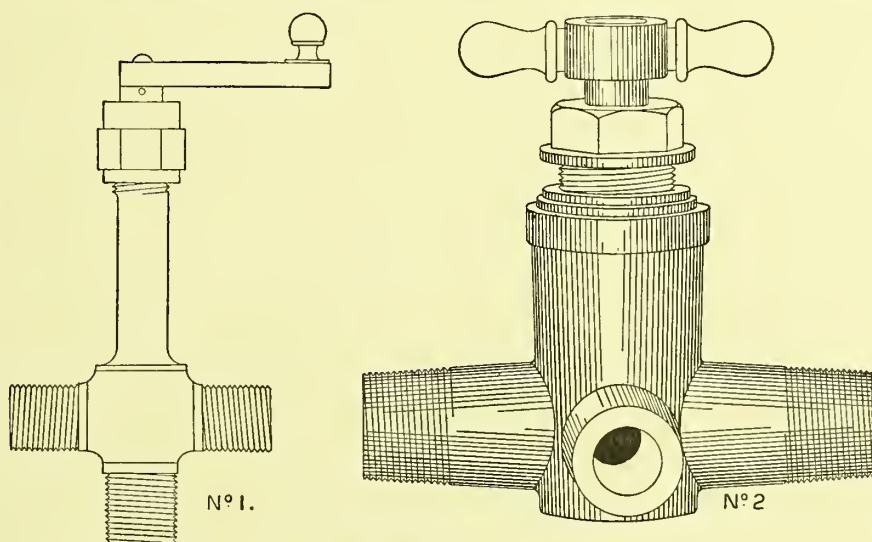


Fig. 904.—Stop Cocks for Small-bore Apparatus

They must be properly loaded according to the pressure they are intended to carry, so as to make them safe in operation.

Stop cocks for small-bore apparatus may be obtained with two, three, or four ways. The two latter varieties differ from ordinary stop cocks, inasmuch as the circulation cannot be completely turned off. When one circuit is shut off, the remaining circuit or circuits connected to the same stop cock are not shut off, but receive the whole of the heat from the fire. Two kinds of stop cock are shown in fig. 904, No. 2 being Perkins's improved pattern. Stop cocks, if used at all, require to be judiciously arranged, so that the system will not be endangered in any way by their use.

An automatic regulator should be fixed in conjunction with the boiler coil when stop cocks are used, in order that the fire may be automatically controlled.

Boilers for small-bore apparatus are made in a variety of forms, with tubes $\frac{7}{8}$ -in. bore and larger. For a very small system a simple coil of pipe (fig. 905) will suffice. If the installation is of considerable magnitude, a

single boiler coil would be inadequate, as the water would be nearly cold when it had completed its circuit of the system. By having a number of separate circuits a nearer approach to uniform heating is obtained.

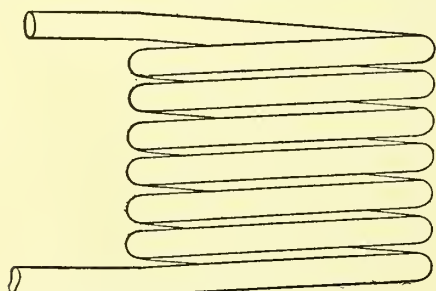


Fig. 905.—Boiler for Small System

Boiler coils for very large installations usually have their circulations crossed. Such a boiler is shown in fig. 906, and consists of eight separate sections, composed of a number of pipes bent and joined together. The flow from the top of the first section is carried to a part of the building to be heated, and the return brought back and joined to the return of the second section; the flow from the second section is taken to heat another part of the building, and that return is brought back and joined to the return of the third section; the remaining six sections are treated in a similar way, the return from the eighth circuit being brought back and joined to the return of the first section. By arranging the pipes in this

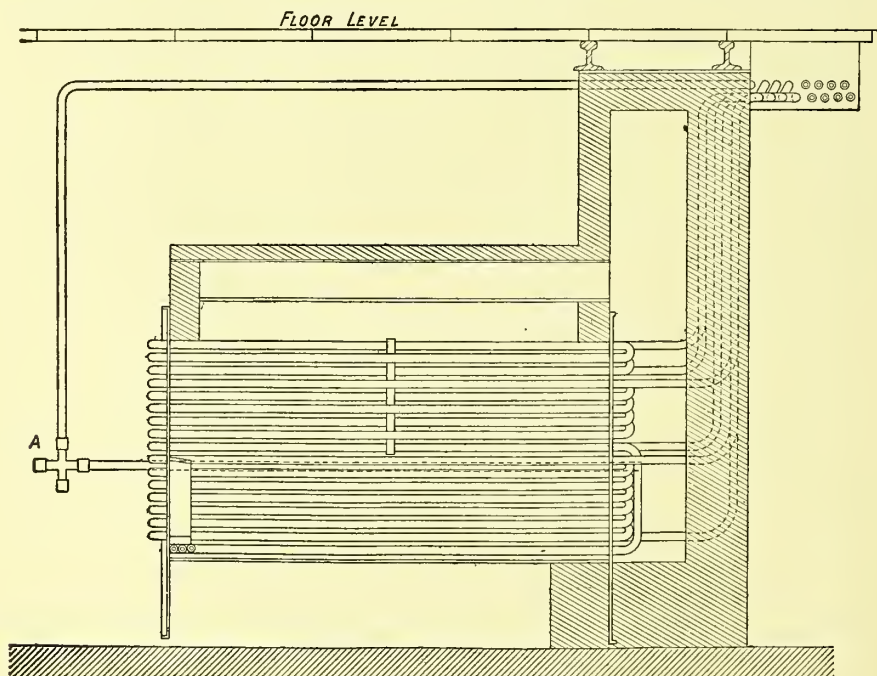


Fig. 906.—Boiler for Large System

way the whole of the sections form one continuous circuit, and only one pumping connection is required, as shown at A, fig. 906. The boilers for large installations are usually set in brickwork, as shown in fig. 906, while the coils for small apparatus are often fixed in iron casings.

The method of crossing the circulations is probably more clearly illustrated in fig. 907, in which three complete circuits are shown. The boiler coils would not actually be arranged as shown, but all three sections would be coiled and interlaced together. By following the pipe round from A to B, it will be observed that the whole forms one circuit. The pumping valve is represented at R, and the expansion tube and filling connection at C. Should an installation be erected with totally separate circulations, each section would require a pumping valve and provision for expansion.

Branched circulations can be arranged by taking the branches from the flow and return pipes as shown in fig. 900, but stop cocks may be required to control the rate of circulation through the different branches; otherwise the circuit which offers the least resistance would have the freest circulation and emit the greatest amount of heat. The air is more difficult to dislodge when branched circulations are adopted.

For filling small-bore apparatus a special form of pumping valve (fig. 908), shown in position in fig. 906, is frequently provided, which allows the water from the pump to be forced into the apparatus in one direction only, and thereby frees it from air when being charged. The advantage of such a fitting is obvious, for without its use the water can flow in

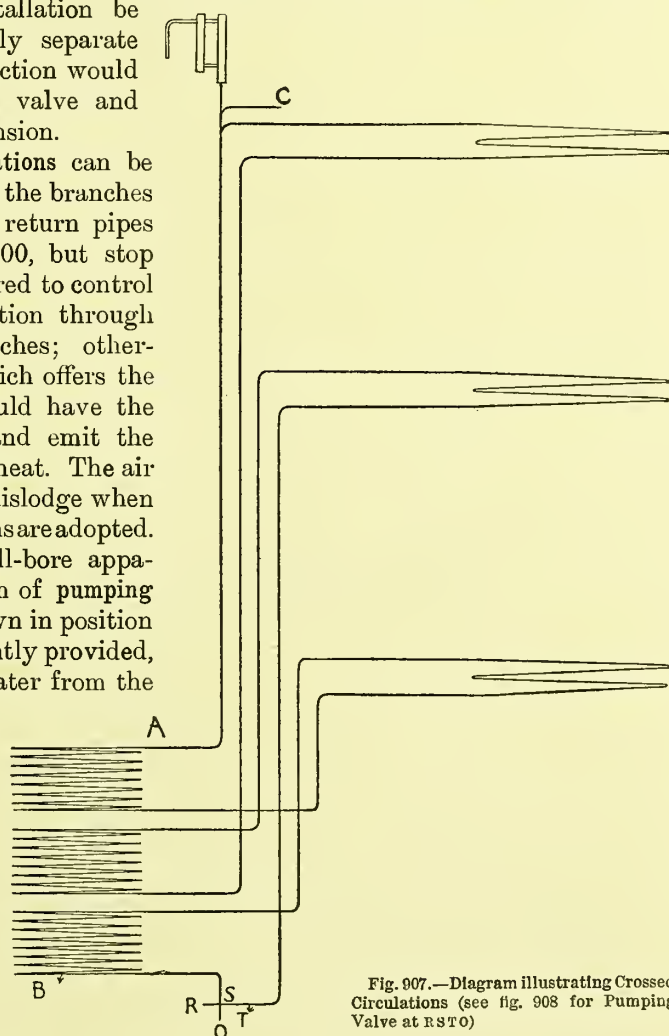


Fig. 907.—Diagram illustrating Crossed Circulations (see fig. 908 for Pumping Valve at RSTO)

two directions, and air is liable to become confined between the two water columns in the flow and return pipes. When pumping, the caps O and R are removed, and a small tube, to which the pump is attached, is inserted at O to push the ball on one side and cause the water to flow through S. As the system is filled, the air is displaced through T and escapes at R. When the apparatus has been charged the cap R can be replaced, and when the small tube has been withdrawn the cap O is also replaced.

Small-bore apparatus should be charged with anti-freezing liquid in lieu of water, especially when installed in places where they are not likely to receive proper attention.

Recharging.—Although the high-pressure system is hermetically sealed, a little water requires to be added occasionally. All metals are slightly porous, hence the loss is easily accounted for, and more especially so when water is converted into the gaseous state. Water, of course, can be added

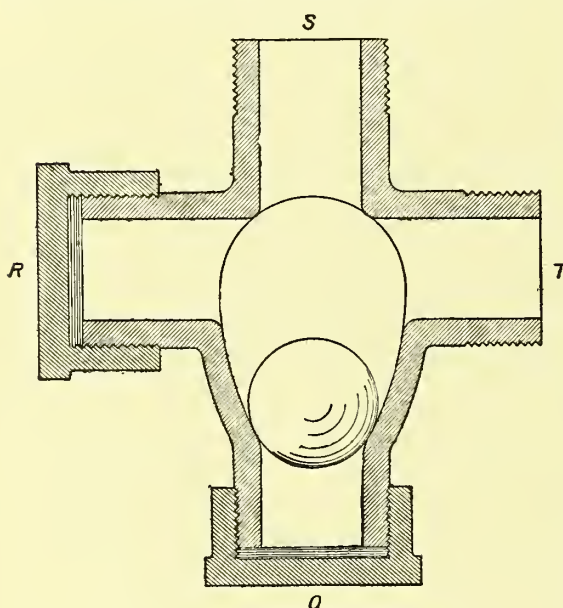


Fig. 908.—Pumping Valve (see fig. 907)

to the high-pressure system only when it is cold, but with a medium-pressure apparatus water or prepared liquid may be added at any time. Should a system be short of water, more space for steam is provided, the circulation is stopped, and thumping noises are heard. A casual noise in a system may be due to overfiring, and the draught requires to be checked.

Drying Rooms, &c.—The high-pressure system of heating is not suitable for dwellings and similar buildings, but it is well adapted for purposes where very high temperatures are re-

quired, such as drying rooms, japanning rooms, and bakers' ovens. It can also be used for heating water for trade purposes, boiling pans, hot plates, superheaters, and evaporators. A greater range of temperature can be obtained by this system of heating than by any other. For example, a room may be heated to less than 60° F. and a baker's oven to over 500° F.

The amount of heating surface for different buildings and inside temperatures to 100° F. may be found by formula (21a), in conjunction with the coefficients given in Table X, Chapter V.

$$l = \{.06 C n + 1.2 W + 4.2 G\} \left\{ \frac{T - 30}{(P - T)f} \right\} \quad . \quad . \quad (21)$$

For internal temperatures not exceeding 70° F.

Where l = length in feet of $\frac{7}{8}$ -in. bore pipe.

„ C = capacity of building in cubic feet.

„ n = number of times air of apartment is changed per hour.

„ W = area of exposed wall in square feet.

„ G = area of glass in square feet.

„ f = a constant to be taken from Table XVIII.

„ P = temperature of water in pipes.

„ T = internal temperature of apartment.

If $P = 330^{\circ}\text{F.}$, $T = 60^{\circ}\text{F.}$, and the external air 30°F. , the modified formula (21a) is obtained:—

$$l = \frac{Cn}{420} + \frac{W}{20} + \frac{G}{6} \quad . \quad . \quad . \quad . \quad . \quad . \quad (21a)$$

TABLE XVIII.—COEFFICIENTS FOR HIGH-PRESSURE HEATING

Difference of Temperature. $P - T =$	Value of $f =$	Difference of Temperature $P - T =$	Value of $f =$	Difference of Temperature $P - T =$	Value of $f =$
80°F.	1.92	130°F.	2.15	180°F.	2.36
90°	1.97	140°	2.19	190°	2.40
100°	2.02	150°	2.23	200°	2.44
110°	2.07	160°	2.27	250°	2.70
120°	2.11	170°	2.36	300°	3

The proportion of boiler coil to radiating pipes varies chiefly according to the temperature desired and the rate of combustion. The values given in Table XIX are approximate. The boiler surface should be arranged and proportioned to prevent undue waste of fuel.

TABLE XIX.—AMOUNT OF $\frac{7}{8}$ -IN. BORE PIPE IN HIGH- AND MEDIUM-PRESSURE HOT-WATER HEATING FOR EACH 1000 CU. FT. OF SPACE, WHEN THE OUTSIDE TEMPERATURE IS ABOUT 30°F.

Internal Temperature Required, in Deg. F.	Length of $\frac{7}{8}$ -inch Pipe per 1000 Cubic Feet.	Ratio of Boiler to Radiating Surface.
50°	10 lin. ft.	$\frac{1}{10}$
55°	12 "	$\frac{1}{10}$
60°	16 "	$\frac{1}{10}$
65°	19 "	$\frac{1}{10}$
70°	24 "	$\frac{1}{10}$
75°	32 "	$\frac{1}{10}$
80°	40 "	$\frac{1}{9}$
85°	53 "	$\frac{1}{9}$
90°	69 "	$\frac{1}{9}$
95°	88 "	$\frac{1}{9}$
100°	110 "	$\frac{1}{8}$
120°	130 "	$\frac{1}{8}$
140°	165 "	$\frac{1}{8}$
160°	230 "	$\frac{1}{7}$
180°	320 "	$\frac{1}{7}$
200°	364 "	$\frac{1}{7}$

CHAPTER X

LOW-PRESSURE STEAM HEATING

Latent heat is the amount of heat required to convert a solid into a liquid, or a liquid into a gas. The latent heat of steam at 212° F. is said to be 966, meaning that 966 B.T.U. are required to change 1 lb. of water at 212° F. into steam at the same temperature. If 1 lb. of water at 40° F. is converted into steam at 212° F., the quantity of heat absorbed in the process is $(212 - 40) + 966 = 1138$ B.T.U.

The latent heat of steam is a variable amount, and its values for different pressures and temperatures are given along with other particulars in Table XX; but in the limited range of low-pressure steam the total heat available does not differ very much. For example, the heat given out by 1 lb. of steam at 3 lb. pressure when condensed into water, which is further cooled to 40° F., is 1140 B.T.U., as shown by the following simple calculation. From Table XX it will be seen that with a pressure of 3 lb. the temperature is 222° F., and the latent heat of steam for that temperature is 958. Therefore the total heat given out equals $(222 - 40) + 958 = 1140$ B.T.U. Steam at atmospheric pressure, when converted into water at 40° F., gives up $(212 - 40) + 966 = 1138$ B.T.U. Thus a difference of 3 lb. steam pressure is represented by a difference of 2 B.T.U. per pound of steam condensed in favour of the higher pressure.

The boiling-point of water varies according to the pressure to which the water is subjected. When water is heated in an open pan, and the barometer records 29.92 in. of mercury, it boils at 212° F. By confining water in a closed boiler in order to generate steam which exceeds the pressure of the atmosphere, free ebullition does not take place until the water is hotter than 212° F.

Volume of Steam.—One cubic foot of water at the pressure of the atmosphere would yield 1642 cu. ft. of steam at the same pressure. This property of steam is specially convenient, as the water line of a heating boiler is not greatly affected when steam is being generated or when the condensed water is returned to it as the heating system cools. The volume of steam varies with the pressure. Thus steam at 10 lb. pressure would only occupy 996 cu. ft., as against 1642 cu. ft. at atmospheric pressure.

"Absolute" pressure is the gauge pressure *plus* the pressure of the atmosphere; thus 0, 1, 5, and 10 lb. gauge pressures would read 14.7, 16, 20, and 25 lb. "absolute" pressures.

Hot Water and Steam Compared.—The difference in the amount of heat in steam pipes and water pipes at the same temperatures is very great. Let it be assumed that there are two heating systems, one containing hot water at 180° F. and the other steam at a pressure of 5 lb. per square inch (228° F.), and that the capacity of each apparatus is equal to the space occupied by 1000 lb. of water at 180° F. If we calculate from a temperature of 60° F., the total heat in the water will equal $(180 - 60) \times 1000 = 120,000$ B.T.U. To find the weight of steam the apparatus will

hold, it is first necessary to know its capacity in cubic feet. The capacity can be found by dividing the weight of water by 60·55, which is the weight of 1 cu. ft. of water at 180° F. Therefore the capacity of the apparatus is $1000 \div 60\cdot55 = 16\cdot51$ cu. ft. From Table XX it will be found that 1 lb. of steam at 5 lb. pressure occupies 19·72 cu. ft. Therefore the weight of steam in the apparatus equals $16\cdot51 \div 19\cdot72 = \cdot837$ lb. The total heat in ·837 lb. of steam above 60° F. equals $(\cdot837 \times 952\cdot8) + (228 - 60) = 965\cdot5$ B.T.U. Thus, in the installations given, the heat in the water exceeds that in the steam by 119,034 B.T.U.

The calculation serves to prove that an installation can be quickly cooled where steam is the heating agent; whilst, when water is used, a considerable time is required, owing to the large amount of heat it contains. The calculation also shows that the velocity at which steam flows through pipes in order to renew the heat at the surfaces must be very much greater than that required by water.

TABLE XX.—PROPERTIES OF SATURATED STEAM

Absolute Pressure. Pounds per Square Inch.	Gauge Pressure. Pounds per Square Inch.	Boiling Point. Deg. F.	Latent Heat per Pound in B.T.U.	Volume of Steam Generated from 1 cu. ft. Water, 62°.	Space Occupied in Cubic Feet per Pound of Steam.	Weight of 1 cu. ft. of Steam in Pounds.
10	...	193·3	978·4	2360	37·84	·0264
11	...	197·8	975·2	2157	34·62	·0289
12	...	202	972·2	1988	31·88	·0314
13	...	205·9	969·4	1844	29·57	·0338
14	...	209·6	967·7	1721	27·61	·0362
14·7	...	212	966	1642	26·5	·0379
15	...	213·1	964·3	1611	25·85	·0387
16	1	216·3	962	1516	24·32	·0411
17	2	219·6	959·8	1432	22·96	·0435
18	3	222·4	957·7	1357	21·78	·0459
19	4	225·3	955·7	1290	20·7	·0483
20	5	228	952·8	1229	19·72	·0507
21	6	230·6	951·3	1174	18·84	·0531
22	7	233·1	949·9	1123	18·03	·0555
23	8	235·5	948·5	1075	17·26	·0580
24	9	237·8	946·9	1036	16·64	·0601
25	10	240·1	945·3	996	15·99	·0625
26	11	242·3	943·7	958	15·38	·0650
27	12	244·4	942·2	926	14·86	·0673
28	13	246·4	940·8	895	14·37	·0696
29	14	248·4	939·4	866	13·90	·0719
30	15	250·4	937·9	838	13·46	·0743

Steam-heating Definitions.—*The main or distributing pipe* starts from the boiler, and conveys steam to supply the heating surfaces. It is usually horizontal, and fixed in a basement or other suitable position.

The return main intercepts the water of condensation and returns it to the boiler. When a return main is fixed so that it will fill with water, it

is sometimes termed a *wet return*; and when it is fixed above the water line, as in the one-pipe system, it is called a *dry return*.

Risers are vertical pipes connected to the mains, and carry steam directly to the heating surfaces, and return the water of condensation. Those which convey steam to the radiators are termed *steam risers*, and those which return the water of condensation are called *riser returns*.

A *relief or drip* is a pipe used to drain condensed water from dips or pockets where water collects, and to deliver it into another part of the system below the water line of the boiler.

Relay indicates a sudden change of alignment of a horizontal pipe, or an immediate rise with a relief pipe attached at the lowest point. A relay is often necessary in long stretches of horizontal pipes where it is desired to fix the pipes near the ceilings, or where the ceiling of one room is lower than the ceiling of the adjoining room.

Water line denotes the level of the water in the boiler and in the returns. The water in the return main will stand higher than the water line of the boiler owing to loss of steam pressure in the return main. In steam systems where the returns are open to the atmosphere, the water will stand in the return main at a height equivalent to the steam pressure of the boiler.

Two very important points in steam heating are the displacement of air from the pipes and radiators, and the efficient drainage of the condensed water. If air is allowed to remain in a system, the efficiency of the heating surfaces is greatly impaired; and if the water of condensation is allowed to collect in dips or pockets, annoyance will be caused by "hammering" noises in the pipes.

Water-hammer in steam pipes is frequently set up when condensed water collects in dips and where this water has cooled prior to steam being generated or turned into the system. When steam comes in contact with cold water, the former is immediately condensed, and a partial vacuum formed. The accumulated water at once rushes to fill the vacuum, with the result that it is precipitated against a bend or other fittings with considerable force. Other hammering or clicking noises of a less violent nature occur when steam and condensed water meet. The exact place where the hammering occurs may be difficult to locate, especially when the hammering is intermittent.

The **gravity-return system** is generally adopted, and in this the pipes may be arranged in different ways, but in each case the water of condensation is returned to the boiler by gravitation and without mechanical aid. Such systems have the advantage of requiring very little attention, as the water line of the boiler remains nearly constant. Water, however, requires to be periodically added to boilers to replace loss by the escape of steam through defective fittings and through the safety valves. The waste of steam through the safety valves can be avoided to a great extent by fitting to the boiler a good damper regulator, so as to control the draught and prevent overheating.

A simple apparatus is illustrated in fig. 909, but is not generally used, as the conditions under which it would work satisfactorily are seldom obtain-

able. The pipes must be large in size, and the horizontal pipes require to be short and have a good pitch. The steam flows from the boiler to the radiators, and the condensed water returns through the same pipes. When the water of condensation and steam travel through the same horizontal pipe, and in opposite directions, there is a possibility of "kicking" or "hammering" noises being caused. The boiler fittings are not shown in the illustration.

Methods of Piping.—

The gravity-return systems may be divided into three classes, viz. *one-pipe*, *two-pipe*, and *overhead* or *drop*.

In each system the horizontal pipes are arranged, as far as possible, so that the steam

and water of condensation travel in the same direction. In the one- and two-pipe systems this is accomplished by making the highest part of the steam main immediately above the boiler, and giving the steam and return

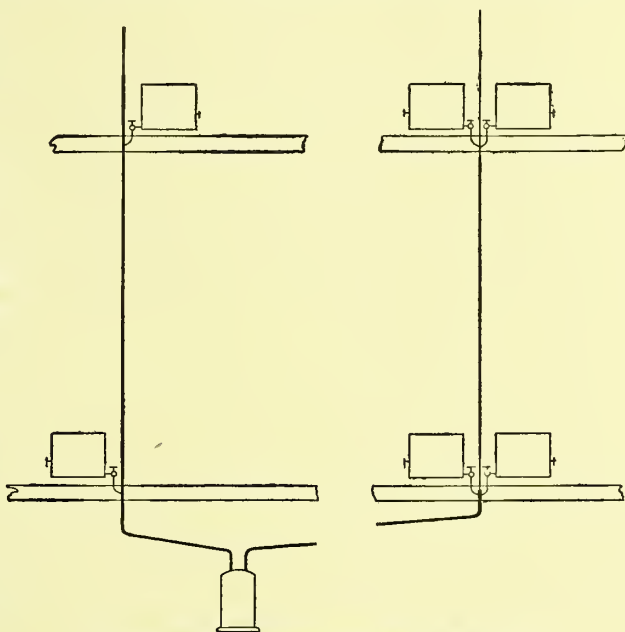


Fig. 909.—Simple Steam-heating Apparatus (One-pipe System)

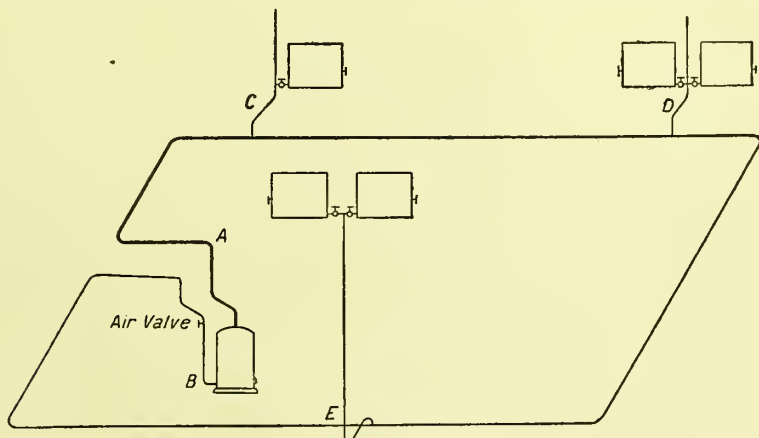


Fig. 910.—One-pipe Gravity-return Apparatus

mains a gradual fall to the boiler. Vertical pipes are often arranged so that steam and condensed water flow in opposite directions, but the objectionable feature of this can be partly overcome by increasing the sizes of the pipes.

One-pipe Work, with Steam above Atmospheric Pressure.—In the one-pipe system, shown in fig. 910, the steam main is supposed to be fixed in the basement of the building. From the bend A the main descends and enters the boiler at B. Three risers, C D E, join the radiators and the steam main. The only places where steam and condensed water flow in opposite directions are in the risers and the short vertical part of the steam main. The arrangement is very simple, and, where properly installed, with pipes of the correct size, it will work satisfactorily. More care, however, requires to be exercised in installing a steam than a hot-water heating apparatus, owing to the difficulty in disposing of the condensed water.

Radiator Valves.—All ordinary steam systems whose heating surfaces use steam above atmospheric pressure have the disadvantage that the

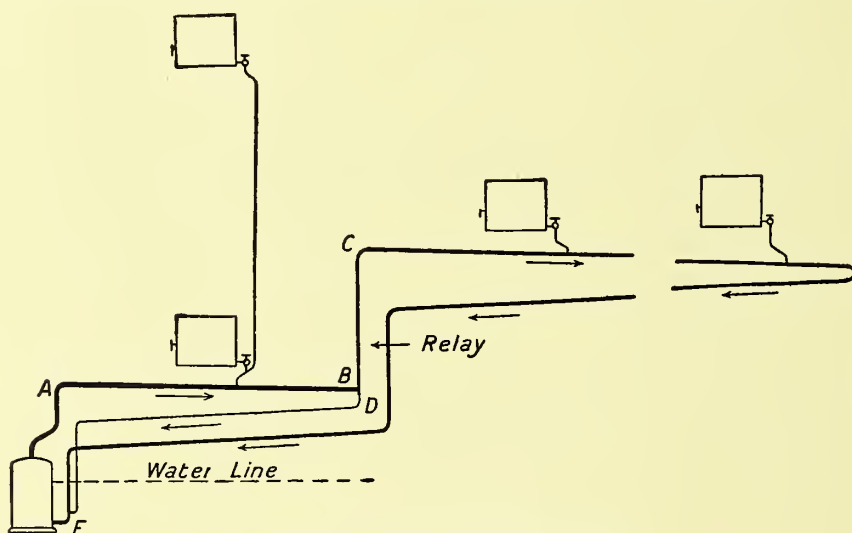


Fig. 911.—Two-pipe System with Relay (B to C)

radiator valves cannot be adjusted to moderate the heat from the radiators; the valves must either be full on or quite off. Assuming that the valve of one of the radiators in fig. 910 were partly closed, the aperture would be too contracted to admit the passage of the steam and of the water of condensation at the same time. As the steam in the riser would possess the greater pressure, it would force its way into the radiator and hold back the condensed water, and might possibly discharge it through the air valve on to the floor of the apartment.

An automatic air valve is shown on the return main (fig. 910) a little above the water line. As air is a little heavier than steam, it tends to seek the lower level in the return main. In hot-water heating the air outlets are fixed at the highest points, but in steam heating they are fixed in lower positions.

Relays.—If a boiler is fixed in a cellar, and the steam main is required to run across the walls in a higher part of the building, the pipes can be arranged as in fig. 911. The steam main falls from A to B and rises

from B to C, the rise being known as a *relay*; from C the main has a downward course all the way to the boiler. To avoid water being trapped at B, a relief D is fixed, which conveys the water of condensation into the return main at E. This relief may be called a *relay relief*.

Two-pipe System (Gravity Return) with Steam above Atmospheric Pressure.

—The two-pipe system has numerous advocates. The chief advantage attributed to it is that it is less liable to water-hammer than the one-pipe system. It is, however, more costly to install. In the two-pipe system the water of condensation from the radiators or other heating surfaces is delivered in the return mains by means of separate riser returns, the object being to prevent steam and water from coming into conflict and to avoid noise. The radiators have flow and return connections, with a valve to each. Both valves must be closed or opened simultaneously in connection with each radiator if the system is to work properly. Should an inlet valve be closed and the outlet valve be left open, condensed water would enter by way of the return, and in some cases fill the radiator. On the other hand, if the outlet valve is closed and the inlet valve left open, the action would be the same as that described

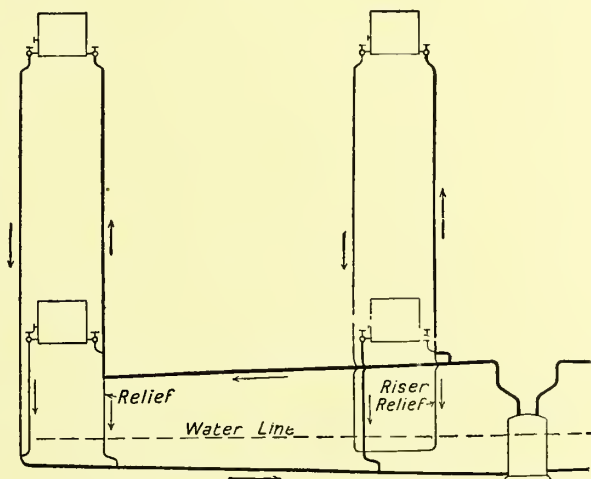


Fig. 912.—Two-pipe System with Riser Reliefs

in connection with the one-pipe system. In either case such irregularity of action would give trouble and be accompanied with more or less noise.

In the two-pipe system (fig. 912), as in the one-pipe system, the steam main rises immediately to its highest point, and then takes a descending course to the boiler. The pipes may be a little smaller in the two-pipe system, owing to the better separation of steam and condensed water. The return main differs from that of the one-pipe system in being fixed below the water line of the boiler. When the return risers are connected with each other, instead of being separately connected with the return main, the branches should be made below the water line of the boiler as well. The advantage obtained by connecting several return risers or relief pipes together is one of cost. Small tees, of course, are cheaper than large ones.

The reason for connecting the return risers as shown in fig. 912 is to prevent steam from entering the radiators by any other passages than those specially provided for it.

Another system of piping is shown in fig. 913. In this case the radiators which are immediately over each other have their return connections joined to one riser return, and the steam can gain admittance to the radiators, when

more than one are in use, through the returns, as well as at their inlet connections. When steam can flow in the directions named, the escape of the condensed water is somewhat impeded. This method of connecting two or more radiators to one riser return is often adopted in America, but the branches must be well arranged to prevent noises. The separate relief from each floor, as shown in fig. 912, makes that system a little more expensive to install, but has the advantage of being nearly silent in action.

Overhead or Drop System, with Steam above Atmospheric Pressure.—In this system (fig. 914) all exposed mains should be well covered with non-conducting material to prevent undue loss of heat. The steam and condensed water flow in opposite directions in the vertical steam main,

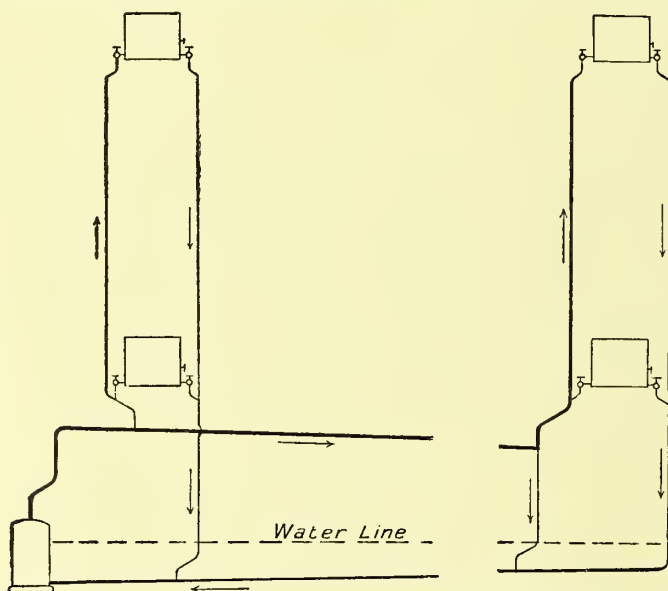


Fig. 913.—Two-pipe System with Two Radiators connected to One Riser Return

but this will not cause any trouble if the pipe is sufficiently large and arranged as shown. The steam main is taken as directly as possible to the highest part of the building, and vertical pipes are dropped from the overhead horizontal mains to feed the radiators on the different floors. The radiators that are connected to the vertical returns require only one connection, while those connected with the vertical steam main should be arranged as shown in the figure. A relief, B, drains the water of condensation from the steam main A. The vertical returns are connected to the return main below the water line of the boiler. The branches to those radiators which are supplied with one connection only should be as short as possible, and sufficiently large to allow the passage of steam and condensed water at the same time. Radiators or other heating surfaces do not usually receive steam from the ascending main A, and are better if supplied by a vertical return. The highest place in the steam main is at c, from which point it takes a downward course.

The overhead system is positive in action, and suitable for large buildings, such as works, factories, warehouses, &c.

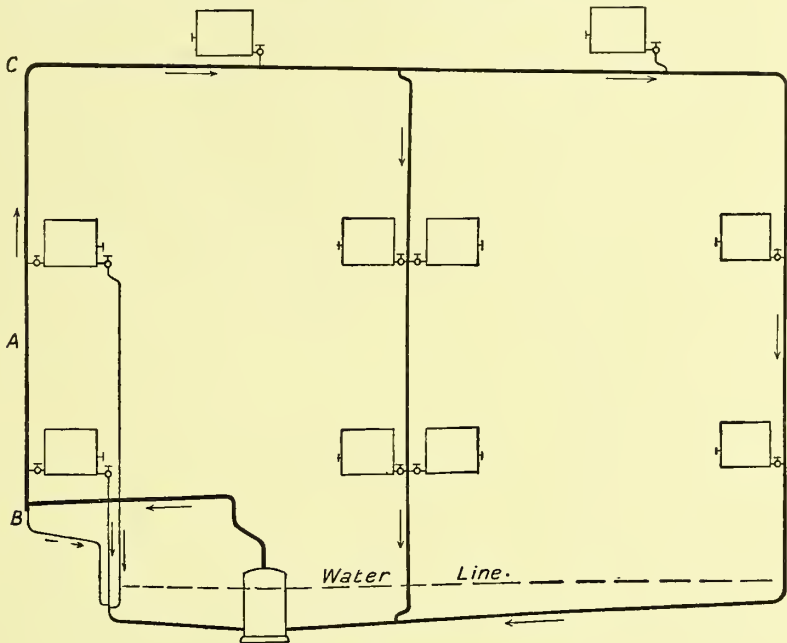


Fig. 914.—Overhead or Drop System of Piping

Artificial Water Lines.—Fig. 915 illustrates an arrangement of trapping to form artificial water lines in a two-pipe system where the riser returns cannot be taken below the boiler water line. If the traps were dispensed with, steam would enter the radiators by both connections. These traps must be fairly deep in order to prevent water being forced out of them by fluctuations of the steam pressure.

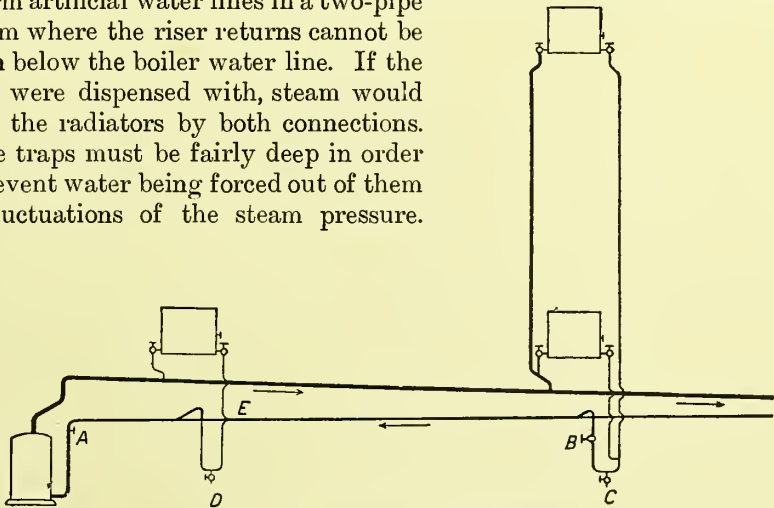


Fig. 915.—Trapped Returns (Two-pipe System)

Small pet cocks C and D (fig. 915) are fixed to the bottom of the traps, so that they can be emptied of water in the event of the apparatus being out of use, and when there would be a danger of the water being frozen.

A better method of forming an artificial water line, where the return main cannot be laid below the water line of the boiler, is shown in fig. 916. All the ends of the riser returns in this case can be properly submerged by joining the horizontal return main B. To make an artificial water line, all that is necessary is to "jump" the return main up just before it descends to enter the boiler. In order to prevent the water being forced or siphoned out of the return main, the steam main and the raised part of the return main are connected by a small pipe A, which tends to equalize the pressure on both sides of the artificial water line. Without the small pipe A the pressure in the pipe D would often be less than that in the steam main, and, sooner or later, the artificial water line would disappear, and hammering and other irregularities would be the result.

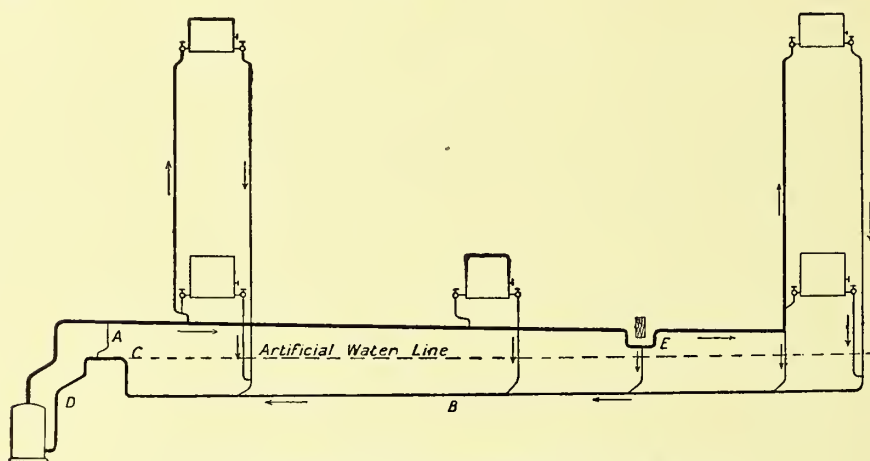


Fig. 916.—Trapped Return Main, and Trapped Steam Main (E) with Relief

Reliefs for Trapped Pipes.—It often happens that pipes have to pass under girders, &c., traps being formed as shown at E, fig. 916. At the bottom of the dip a relief must be fixed to convey away the condensed water which would tend to gather there. If the relief cannot be intercepted by a submerged return, or connected below the water line of the boiler, it must discharge into a steam trap.

Steam Traps.—When a steam radiator or coil is fixed at a lower level than the boiler, a steam trap or similar appliance becomes imperative. If a return from such a radiator is taken back to the boiler or joins the return main, the radiator will fill with water and be rendered useless. The purpose of a steam trap is to prevent waste of steam and receive water of condensation. In buildings where the heating surfaces cannot be arranged so that the whole of the condensed water will gravitate to the boiler, the mains should be arranged to convey back as much as possible; the remainder of the water of condensation can then be delivered into a steam trap or other suitable fitting.

Use of Condensed Water.—It is a very common practice to allow small quantities of condensed water to run to waste; but if the point of discharge

is near the boiler, small quantities of condensed water at a high temperature may be often advantageously returned to a cistern and re-used as feed water for the boiler. To replace hot by cold water means that additional fuel must be consumed. In the one-pipe system, shown in fig. 917, the risers A, B, C, D, and E return their water of condensation to the boiler in the ordinary way, but three radiators are fixed below the boiler or in such a position that the condensed water from them cannot gravitate to it. This condensed water is discharged into a steam trap T, from which it is delivered by the pressure of the steam into the feed tank M to be re-used.

If the three radiators in fig. 917 contain 156 sq. ft. of heating surface, they will condense approximately 50 lb. of steam per hour. If the hot water of condensation is allowed to drain to waste, more fuel will be required to generate the requisite steam. A simple calculation will make this clear. Fifty pounds of water must be supplied to the boiler in any

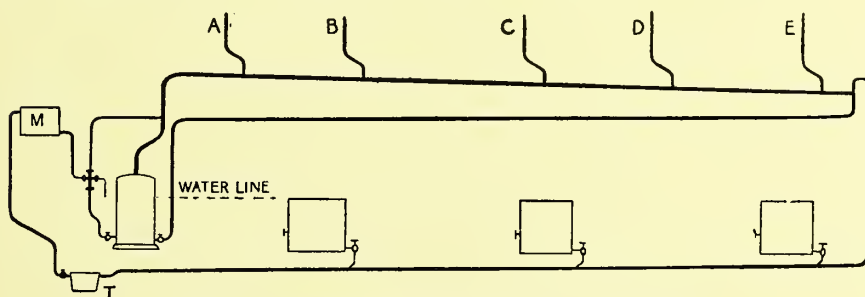


Fig. 917.—One-pipe System with Steam Trap T and Feed Tank M

case per hour, so that the only thing that needs consideration is the difference in temperature at which the water enters the boiler. Taking the temperature of the cold supply at 50°F. , and the condensed water in the tank at 180°F. , the difference in temperature is $180 - 50 = 130^{\circ}$. To raise 1 lb. of water through 130 degrees requires 130 B.T.U., and $130 \times 50 = 6500$ B.T.U. for 50 lb. of water. Thus the saving effected by returning the water to the boiler instead of letting it flow to waste, for the conditions stated, and for a period of ten hours, would be 50 gal. of water and not less than 12 lb. of fuel for certain types of boiler.

In systems where condensed water runs to waste, the water gauge of the boiler requires to be kept under constant observation, so that the water line shall not sink too low and allow the boiler plates to be burned. For large heating installations, where big volumes of condensed water cannot flow by gravity to the boiler, it is usual to pump it back.

The cost of heating by steam is usually less when the steam can be supplied from a power boiler than when it is specially generated in a low-pressure boiler, but in the former case the whole of the water of condensation requires to be pumped back.

Pipes.—When the pipes are arranged for steam heating, the branches are made in a similar way to those described for hot-water work; but more care must be exercised, as the expansion and contraction are greater and more rapid. To prevent leakage by broken and strained joints, the pipes

must be fixed so that movement in the direction of their length can take place. Expansion bends should be inserted in long, straight lengths of pipe, and stiff or rigid branches should be avoided by making off-sets at the ends of the vertical pipes before joining a horizontal main.

The connections of steam pipes with radiators are also made in the same way as those in hot-water work. The fittings should be such that they will not allow water to collect in them.

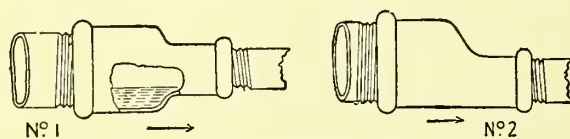


Fig. 918.—Reducing Sockets

fig. 918) are not suitable for diminishing the sizes of horizontal steam pipes, as water lies in them, and the presence of water in pipes is conducive to clicking and hammering, especially when steam is first turned on. When these fittings are used a relief should be fixed to drain off the water. A relief may be dispensed with by fixing the special reducer in the position shown in No. 2, fig. 918. This preserves the true alignment of the pipes,

The common forms of reducing sockets (No. 1, and so long as the pipes have a pitch the condensed water will drain away.

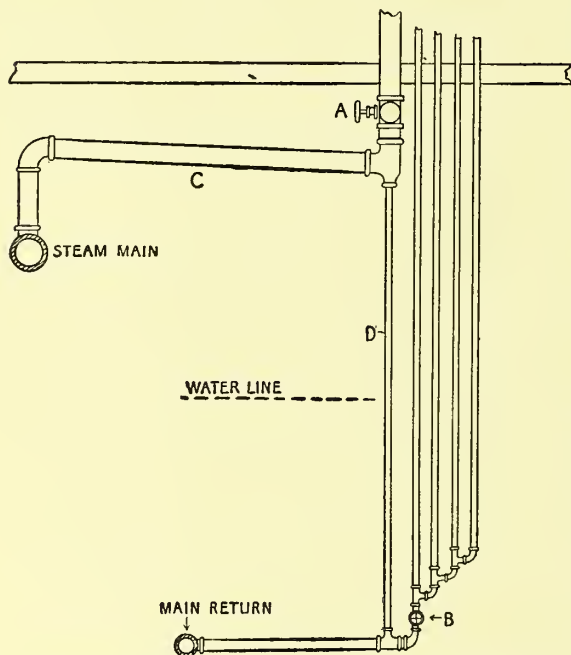


Fig. 919.—Stop Cocks on Steam Main at A and on Riser Return at B

Stop cocks or valves may be fixed on risers, so that steam can be shut off from a number of radiators or from a section of a building, in the boiler house or other convenient place (fig. 919). If a stop cock is fixed on the steam riser, one will also be necessary on the riser return, to prevent the water of condensation backing up it when the steam valve is closed. In fig. 919 one steam riser is shown and four riser returns. The valve of the steam riser is fixed at A, and one valve for the riser returns is fixed at B. This arrangement allows the cir-

ulation to be maintained between the steam main and return main, by the pipe D, while at the same time the steam is effectively shut off from the radiators or section desired. Supposing the steam valve were fixed in the horizontal pipe at C, instead of at A in the vertical pipe, another valve would be required in the riser relief D to prevent the water backing up at that point; but this method would not be nearly so good as the one shown.

The best steam valves are those which have clear or fullway passages through them, such as the gate type. The globe pattern, when fixed on horizontal pipes, collects water, which causes crackling sounds. This trouble can be overcome by fixing the valves nearly on their sides; but their construction causes them to interfere too much with the free flow of steam. The valves for steam radiators are usually of the angle pattern, like those used in connection with hot-water radiators.

At the point where the return main enters the boiler a check or non-return valve is usually necessary to prevent water from the boiler being forced into the return main, either when overfiring occurs, or by fluctuations of the steam pressure. The difference in pressure between the steam in the boiler and that at the end of the return main should be very little in gravity-return systems. Where the lowest radiators are about 4 ft. higher than the water line of the boiler, the fall in the steam pressure should not exceed 1 lb., and if the radiators are only 2 ft. above the water line of the boiler, the difference in pressure should not be more than $\frac{1}{2}$ lb. A swinging pattern non-return valve, for fixing in a horizontal position, is shown in fig. 920. These valves should have a full way through them, and their seating should be raised and have only a small bearing so as to minimize the risk of sticking.

Automatic Air Valves.—Air valves are required on radiators, coils, and pipes, so that the air which tends to accumulate can be discharged from them. Air is much more difficult to displace from steam than from hot-water heating apparatus. Steam is lighter than air, and the natural inference is that the latter will seek to accommodate itself in the lower parts of a system. Air, however, only occupies the lower position when steam enters the heating surfaces in such a way that actual mixing with air is avoided as far as possible. The difference in weight between 1 cu. ft. of air at atmospheric pressure and 212° F., and 1 cu. ft. of steam at the same temperature is only slightly over $\frac{1}{4}$ oz., and this probably accounts for the difficulty of separating air and steam.

It is a good plan, although not generally adopted in this country, for the steam inlet of a radiator to be fixed at the top, and the outlet at the bottom of the opposite end. The air valve would be fixed near the latter position. This arrangement of the connections would, of course, be applicable only with the two-pipe system. In the one-pipe system the steam inlet is necessarily at the bottom of a radiator, as it serves also to drain away the water of condensation. The air valve in this case should be fixed about two-thirds down the radiator on the side opposite the inlet, as the air and steam tend to mix when the steam enters at the lower level. Should a radiator on the two-pipe system have the steam inlet at the bottom, the air valve should be placed in the position indicated for a one-pipe system.

The valves used for releasing air in steam heating apparatus are generally automatic in their action, and are of two principal kinds—those

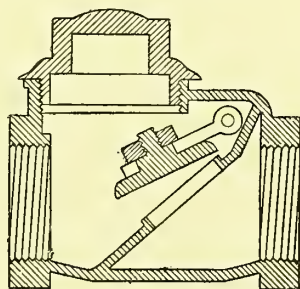


Fig. 920.—Swing Pattern Non return Valve

which operate by expanding and contracting metal parts or composition plugs, and those which open and close by the aid of floats.

Jenkins's Automatic Air Valve (fig. 921) depends upon a special composition for its action. When cold, the composition plug C does not occupy the

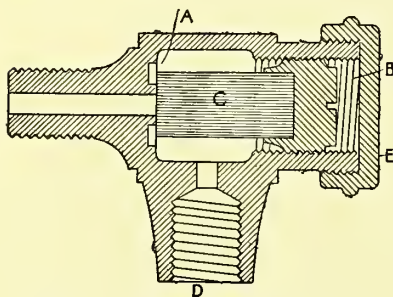


Fig. 921.—Jenkins's Automatic Air Valve

this valve, steam must be blown through until all air is removed and the plug C heated; then the regulating screw B must be gently tightened until no steam escapes. After the protecting cap E has been replaced, the valve will be in working order.

The "Onderdonk" Air Valve (fig. 922) has two strips of different metals bent into the form of a spring. The more expansive metal forms the inner loop, and when steam comes in contact with it the spring loop opens, and closes the outlet by a spindle to which it is attached. A float F is also connected with the spindle, and should a radiator at any time partly fill with water, the float would rise, close the valve, and prevent water escaping. The ordinary expanding plugs allow water to escape from the valves if water rises into the radiators.

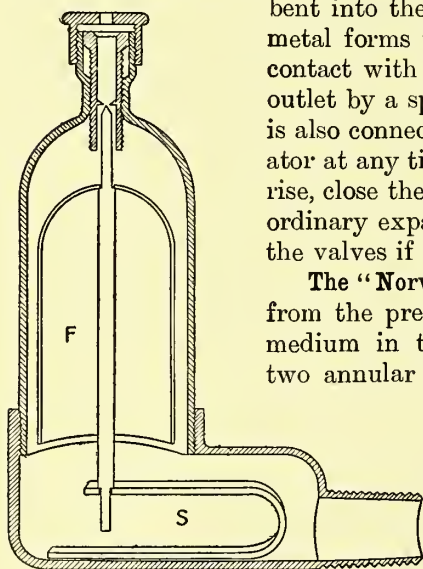


Fig. 922.—The "Onderdonk" Air Valve

The "Norwall" Automatic Air Valve (fig. 923) differs from the previous valves inasmuch as the expanding medium in this case is air. The valve consists of two annular spaces A and B, the latter surrounding the former, and the compartments communicating by an aperture at C. The float D rises and falls according to the expansion and contraction of the confined air in the compartment B, and the displacement of water from one annular space to the other. When the valve is first fixed it contains no water, but

after steam has been turned on for a short time and allowed to blow through the valve, some of the steam condenses, until sufficient water has accumulated in the space A to raise the float and close the outlet E; at the same time the confined air in the space B is expanded by the heat and tends to dislodge any condensed water that may have entered it. If now air should gather at the point where the valve is fixed, the latter gradu-

ally begins to cool, the confined air in the compartment B contracts, and water from the chamber A enters B to supply the void formed. The float D immediately falls and allows the accumulated air to escape. As soon as steam again comes in contact with the valve the air in the chamber B is expanded, and the water forced out of it into chamber A; the water in turn buoys up the float and again closes the valve. The water in fig. 923 is shown up to the level of the inlet, and if any further steam is condensed in the valve, the superfluous water, of course, simply escapes into the radiator and drains to the outlet. This valve is made entirely of metal, and is self-adjusting, sensitive in action, and simple in construction. The float can be readily removed for cleaning, when necessary, by removing the cap F.

Air Pipes.—Air valves usually discharge into the apartment in which they are fixed, but if this is considered objectionable, small pipes may be attached to the valves, to discharge the air in any suitable situation. Most automatic air valves allow air to enter the apparatus when steam is off, and if this air should become stagnant, it may give off an unpleasant odour; this would be more pronounced in “exhaust” than in “live” steam heating. Hydrogen gas is sometimes discharged from an apparatus, owing to the decomposition of steam by contact with heated iron surfaces. This gas has a peculiar odour, but it is doubtful if it is ever discharged from a heating system in sufficient quantity to be noticeable by the sense of smell.

Sizes of Pipes for Low-pressure Gravity-return Systems.—The pipes in gravity-return apparatus are rather large in comparison with those in some of the other systems of steam heating. This is chiefly owing to the low velocity at which steam is permitted to flow through the pipes, in order that the difference in steam pressure at the beginning and end of the circuit may be small.

A number of formulæ for calculating the flow of steam through pipes treat steam as though it were a perfect gas; in fact, the same formula is frequently given for determining the velocity of both steam and air through pipes. Steam, however, tends to condense when flowing through pipes, whilst air retains its original state. Condensation also has the effect of reducing the pressure in steam pipes.

In the one-pipe system the pipes require to be larger than in the two-pipe system, as the water of condensation must be accommodated in the same pipes as the steam. It may be thought that, owing to the great difference in bulk between steam and water, the diameters of the return

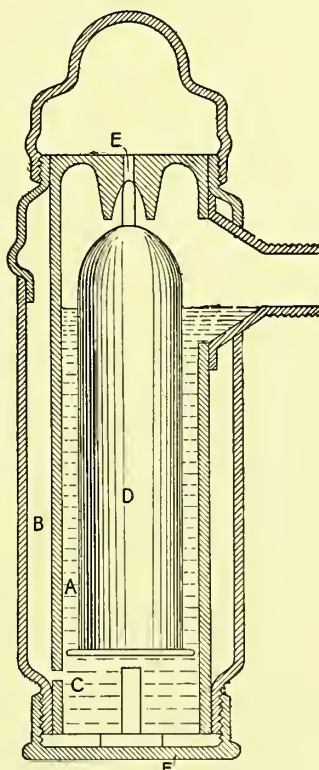


Fig. 923.—The “Norwall” Automatic Air Valve

First find the value of w :—

$$w = \frac{6 \text{ R}}{\text{H}} = \frac{6 \times 2000}{953} = 12.59 \text{ lb.}$$

$$d^5 = \frac{\cdot 0003 \, w^2 l}{p \, D} = \frac{\cdot 0003 \times (12\cdot 59)^2 \times 200}{\cdot 5 \times \cdot 0507} = 375\cdot 1.$$

Upon referring to Table XXI it will be observed that the next higher number to 375.1 is 525.21, and to the left of the latter number on the same line is $3\frac{1}{2}$ in., which gives the diameter of steam pipe required.

The same problem worked by formula (22) gives practically the same result.

$$\text{Thus } d = \sqrt[5]{\frac{.0003 \times (12.59)^2 \times 200}{.5 \times .0507}} = 3.27 \text{ in.}$$

As pipes of this size are not made, the first stock size higher would be used, viz., $3\frac{1}{2}$ in. in diameter.

TABLE XXI

To be used in conjunction with formula (22a).

Diameter of Pipe.	Where $d^5 =$ $\frac{.0003 w^2 l}{p D} =$	Diameter of Pipe.	Where $d^5 =$ $\frac{.0003 w^2 l}{p D} =$
$1\frac{1}{2}$ in.	7.59	$5\frac{1}{2}$ in.	5032.84
2 "	32.00	6 "	7776.00
$2\frac{1}{2}$ "	97.65	7 "	16807.00
3 "	243.00	8 "	32768.00
$3\frac{1}{2}$ "	525.21	9 "	59049.00
4 "	1024.00	10 "	100000.00
$4\frac{1}{2}$ "	1845.28	11 "	161051.00
5 "	3125.00	12 "	248832.00

To find the diameter of steam main for a one-pipe system, multiply the diameter obtained by formulas (22) and (22a) by the constant 1.22. The table on p. 174 gives the sizes calculated in a similar way.

Bends and Connections.—When calculating the lengths of pipes an allowance must be made for bends and connections. For round elbows allow 8 ft. of pipe; quadrant bends, 4 ft.; obtuse bends, 3 ft.; tees, 12 ft.; globe valves, 20 ft.

A simple rule for finding the diameter of a steam main is that based upon the diameter increasing directly as the square root of the heating surfaces. A 1-in. pipe is considered capable under ordinary circumstances of supplying 100 sq. ft. of heating surface. The rule is:—Diameter of steam main in inches equals $\frac{1}{10}$ th of the square root of the total heating surface in square feet. If expressed as a formula, where d = diameter of main in inches, and R = total radiating surface in square feet—

$$d = \frac{\sqrt{R}}{10} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (23)$$

Thus the diameter of a main for 400 sq. ft. of radiation equals $\sqrt{400} \div$

10 = 2 in. For 225 sq. ft. $\sqrt{225} \div 10 = 1\frac{1}{2}$ in. diameter. This rule applies for certain conditions, but the results should be checked by formula (22), as the rule does not take into account the length of pipes, and where the heating surfaces are scattered and the pipes very long the diameters of mains found by it will be too small. On the other hand, where a large amount of radiating surface is distributed over a comparatively small area, the size of main found by rule (23) will be rather large.

TABLE XXII.—SIZES OF STEAM MAIN FOR ONE-PIPE SYSTEM (DIRECT RADIATION)

(Steam pressure, 5 lb. Loss in pressure, 3 in. of water for lengths of 100 ft. and under, and 6 in. of water for greater lengths.—*Heating and Ventilation*, by Professor Carpenter.)

Radiating Surface. Square Feet.	Length of Steam Main in Feet.								
	20	40	80	100	200	300	400	600	1000
	Diameter of Pipe in Inches.								
20	1	1	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$
40	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$
60	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$
80	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{2}$	2
100	1 $\frac{1}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$	2
200	1 $\frac{1}{2}$	1 $\frac{1}{2}$	2	2	2	2	2	2 $\frac{1}{2}$	3
300	2	2	2	2	2	2 $\frac{1}{2}$	2 $\frac{1}{2}$	3	3 $\frac{1}{2}$
400	2	2	2 $\frac{1}{2}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	3	3	3	4
500	2	2 $\frac{1}{2}$	2 $\frac{1}{2}$	3	3	3	3 $\frac{1}{2}$	3 $\frac{1}{2}$	4
600	2 $\frac{1}{2}$	2 $\frac{1}{2}$	3	3	3 $\frac{1}{2}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$	4 $\frac{1}{2}$
800	2 $\frac{1}{2}$	3	3 $\frac{1}{2}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$	4	4	5
1,000	3	3 $\frac{1}{2}$	3 $\frac{1}{2}$	4	4	4	4	4 $\frac{1}{2}$	6
1,400	3 $\frac{1}{2}$	3 $\frac{1}{2}$	4	4	4	4 $\frac{1}{2}$	4 $\frac{1}{2}$	5	6
1,800	4	4	4	4	4 $\frac{1}{2}$	5	5	6	7
2,000	4	4	4	4 $\frac{1}{2}$	4 $\frac{1}{2}$	5	5	6	7
3,000	4 $\frac{1}{2}$	4 $\frac{1}{2}$	4 $\frac{1}{2}$	5	5	6	6	7	8
4,000	5	5	5	6	6	7	7	7	9
6,000	5 $\frac{1}{2}$	5 $\frac{1}{2}$	6	7	7	7	7	8	10
8,000	5 $\frac{1}{2}$	5 $\frac{1}{2}$	6	7	7	8	8	9	11
10,000	6	6	6	7	8	8	9	10	12
12,000	6	7	7	7	8	8	10	11	12
14,000	7	7	7	8	9	9	10	12	14
16,000	7	8	8	9	9	10	11	12	14
18,000	8	8	8	9	10	11	11	12	14
20,000	9	9	9	10	11	11	12	14	16

Where a steam main is used to supply a number of radiators fixed below the boiler, and the water of condensation is drained into a receiver, the steam main can be reduced in size, as the steam can be passed through at a higher velocity, and the steam pressure can be allowed to fall at a greater rate than in systems where the condensed water gravitates to the boiler. It is assumed that the condensed water would be pumped back to the

boiler, but if it is discharged into a lifting steam trap, pipes of the sizes given in Table XXII would be required to avoid undue loss of pressure.

Table XXIII gives the approximate sizes of mains for different quantities of heating surfaces in one- and two-pipe systems. When sizes are taken from tables which omit length of piping, discretion must be used.

TABLE XXIII

Direct Radiation in Square Feet.	One-Pipe System.	Two-Pipe System.	
	Diameter of Steam Pipe in Inches.	Diameter of Steam Main in Inches.	Diameter of Return in Inches.
Up to 150	1½	1¼	1
150 " 370	2	1½	1¼
370 " 500	2½	2	1½
500 " 700	3	2½	2
700 " 1100	3½	3	2½
1100 " 1400	4	3½	2¾
1400 " 1900	4½	4	3
1900 " 2500	5	4½	3
2500 " 3200	6	5	3½
3200 " 4600	7	6	3½
4600 " 6000	8	7	4
6000 " 7400	9	8	4
7400 " 9900	10	9	4½
9900 " 14,000	12	10	5

The diameter of drips or reliefs should not be too large, or they would retard the flow of steam through the mains. If, on the other hand, these pipes are too small, the water of condensation collects and causes trouble. Prof. Carpenter gives the following sizes as satisfactory for general work:—

TABLE XXIV.—DIAMETER OF DRIP OR RELIEF PIPES FOR DIFFERENT LENGTHS OF STEAM MAINS

Diameter of Steam Main.	Length of Main.			
	Up to 100 Feet.	100 to 200 Feet.	200 to 400 Feet.	400 to 600 Feet.
Up to 2 in.	½ in. diam.	½ in. diam.	½ in. diam.	¾ in. diam.
" 3 "	¾ "	¾ "	¾ "	1 "
" 4 "	1 "	1 "	1 "	1¼ "
" 5 "	1¼ "	1¼ "	1¼ "	1½ "
" 6 "	1½ "	1½ "	1½ "	1¾ "

Calculation of Heating Surface.—The values relating to temperature, and the number of heat units emitted per square foot of radiating surface in a given time, differ from those where low-pressure hot water is the heating medium, but the method of calculation is the same. The amount of heat

emitted from a square foot of steam-heated surface largely depends upon whether the air is effectively removed or not, and seldom can a radiator heated by steam compare in efficiency with one heated by hot water, when the difference in temperature, size, and class of surfaces are the same. For horizontal pipes the average amount of heat emitted is 2 B.T.U. per degree difference of temperature per square foot of surface per hour. The average value for radiators is 1.6 B.T.U., and in some cases it may be as high as 1.8 B.T.U.

The total heating surface can be found by formula (8), p. 105.

By substituting values, a more convenient rule is obtained. Let $T = 60^\circ$, $t = 30^\circ$, $P = 222^\circ$, and $u = 1.6$ B.T.U.

$$\text{Then } R = (.021 Cn + .4 W + 1.14 G) \times .1157 \quad . \quad . \quad (24)$$

$$\text{from which } R = \frac{Cn}{410} + \frac{W}{22} + \frac{G}{7.5} \quad . \quad . \quad . \quad (24a)$$

Where $u = 1.8$ B.T.U., and the other values are as above—

$$R = \frac{Cn}{460} + \frac{W}{24} + \frac{G}{8.5} \quad . \quad . \quad . \quad . \quad . \quad (24b)$$

Where $u = 2$ B.T.U. and the other values are as before—

$$R = \frac{Cn}{510} + \frac{W}{27} + \frac{G}{9} \quad . \quad . \quad . \quad . \quad . \quad (24c)$$

Formulae (24a) to (24c) will only be applicable for the conditions stated, viz.: external temperature 30° F., inside temperature 60° F., and steam in pipes at 222° F., which is equivalent to about 3 lb. gauge pressure. To obtain the heating surface required for the same steam pressure, but with different inside and outside temperatures, the coefficients in Table X may be used in conjunction with formulae (24a) to (24c).

Table XXV gives the heating surface based upon the cubic capacity alone; this table saves time when only approximate values are required.

TABLE XXV. — APPROXIMATE RADIATING SURFACES REQUIRED IN LOW-PRESSURE STEAM HEATING. EXTERNAL ATMOSPHERE 30° F. STEAM PRESSURE ABOUT 3 LB. PER SQUARE INCH

Kind of Apartment Heated.	Temperature Required, Degrees F.	1 Sq. Ft. of Radiation Warms.
Workshops and Factories ...	50	200 cu. ft.
Warehouses, &c.	55	150 "
Churches and Assembly Rooms ...	60	130 "
Living Rooms	60	90 "
" " " " " " " " " " " "	65	80 "
Entrance Halls	70	62 "
Drying Rooms'	75	48 "
" " " " " " " " " " " "	80	38 "
" " " " " " " " " " " "	85	29 "
" " " " " " " " " " " "	90	22 "
" " " " " " " " " " " "	100	12 "

CHAPTER XI

LOW-PRESSURE STEAM BOILERS

Low-pressure Steam Boilers may be similar in construction to those for low-pressure hot water, but their design should be such that steam is readily disengaged, in order to avoid "priming", which is caused by an agitated and frothing state of the water, when the separation of the steam from the water is retarded. To prevent priming, the water passages of the boiler must admit of a free circulation, and a large water surface is also necessary.

The water and steam spaces vary in size in different types of boilers, being in the proportion of about 2 cu. ft. of the former to 1 cu. ft. of the latter in sectional boilers, whilst in some other types a larger steam space is provided. The boiler should be sufficiently large to fill the whole system with steam without causing the level of the water line to vary more than about $\frac{3}{4}$ in. The steam space should be as liberal as possible in order to provide a reserve of steam, and avoid particles of water being projected into the steam main. A large water area is an advantage, as it facilitates the disengagement of steam and produces drier steam.

Low-pressure steam boilers are less economical than hot-water boilers, excepting when the rate of firing exceeds 12 lb. of fuel per sq. ft. of grate per hour. The average efficiency of steam boilers is about 80 per cent of the latter; in other words, if a hot-water boiler is capable of transmitting 300,000 B.T.U. to the water in the system, a steam boiler of the same dimensions would give only about 240,000 effective heat units in the same period of time. This difference is chiefly accounted for by the fact that greater losses take place in steam apparatus due to condensation of steam, and a less difference of temperature between the water and the fire sides of the boiler surfaces.

Incomplete combustion is a source of fuel waste in heating boilers, when the dampers and air supply to the furnaces are not properly adjusted. When coal is burning it combines with oxygen to form two oxides, viz.: carbonic oxide (CO) and carbon dioxide (CO₂). Heat is given out by these oxides, but the lower oxide of carbon (CO) will only yield about 4400 B.T.U. per pound whilst the higher oxide (CO₂) gives up about 14,000 B.T.U. To obtain the maximum heat from fuel, the air supply must be sufficient to produce the higher oxide. It is found that about 22 lb. of air are required per pound of coal to supply the necessary oxygen to effect complete combustion. If an excess of air is passed through the furnace, heat is wasted in raising the temperature of the superfluous air.

The amount of heat transmitted per square foot of boiler surface varies considerably with the kind of surface and type of boiler. At one time the following rule for calculating the rate of heat transmittance through boiler plates was in common use:—"The heat transmitted is directly proportional to the area of the plate, to the difference of temperature between the two surfaces, to the conductivity, and to the time, and inversely proportional to the thickness of the plate".

As far as boilers are concerned, this rule is not satisfactory. The rate of conductivity for (say) iron and copper in boilers, for equal areas and thicknesses of plates, is nearly the same, owing to the soot which is deposited on the surfaces. For clean plates of the same thickness the relative conductivities of copper and iron are nearly in the ratio of 6 to 1; but the rate of conductivity of a metal is readily affected when the character of its surface is changed. The thickness of a boiler plate has some influence on the amount of heat transmitted, but not nearly to the extent stated in the rule above.

To ascertain the work a low-pressure steam-heating boiler is capable of doing, it is better to base the calculation on the boiler efficiency and the amount of fuel it is desired to burn on each square foot of grate area. The rating of boilers according to the amount of heating surface they contain is too uncertain, as the ratio of heating surface to grate area varies to such a great extent.

Size of Boiler.—To determine the size of boiler for low-pressure steam, the following formula may be used:—

$$a = \frac{Rr}{wfq} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (25)$$

Where a = area of grate in square feet.

„ R = total radiation in square feet.

„ r = heat emitted per square foot of steam-heated surface per hour (for radiators may be taken as 280 B.T.U.).

„ w = weight of fuel in pounds consumed per square foot of grate per hour.

„ f = calorific value of fuel (see Table XII).

„ q = coefficient depending upon the class of boiler.

Value of q .	Kind of Boiler.
·4 to ·6	Good types of sectional boilers (self-contained)
·35 to ·5	Good types of brick-set boilers
·4 to ·55	Vertical boilers with cross tubes (self-contained)

The fuel consumption for the values q is approximately as follows:—

w = 6 to 9 lb. for brick-set boilers with long horizontal flues.

w = 7 to 12 lb. for sectional boilers with winding flues.

w = 8 to 12 lb. for straight-draught self-contained boilers.

Example.—Find the grate area of a boiler for an installation which contains 1500 sq. ft. of radiation.

We will assume that a good sectional boiler is required, and that 8 lb. of fuel with a calorific value of 14,000 B.T.U. are consumed per square foot of grate per hour, the value of q being (say) ·4.

$$a = \frac{Rr}{wfq} = \frac{1500 \times 280}{7 \times 14000 \times \cdot 4}$$

$$\therefore a = 10\cdot7 \text{ sq. ft. of grate.}$$

The total area of the boiler surface can be found by multiplying the grate area by the values given in connection with hot-water boilers.

The horse-power of a low-pressure steam boiler can be calculated when a standard that constitutes a horse-power is adopted. The standard adopted by the committee of judges at the American Centennial Exhibition in 1876 as a boiler horse-power is the evaporation of 30 lb. of water at 100° F. into steam at 70 lb. pressure. This is equivalent to 33,327 B.T.U., which is the heat required to evaporate the water under the conditions given.

To express the total radiating surface in terms of horse-power, the heat units which constitute one horse-power must be reduced to effective heat units. This can be done by deducting 25 per cent from the number given to allow for losses due to condensation. Thus, $33,327 - 8332 = 24,995$ effective B.T.U. in each boiler horse-power. Taking an average square foot of mixed radiation as emitting 280 B.T.U., $24,995 \div 280 = 89.2$ or (say) 90. Upon this basis one horse-power is capable of supplying 90 sq. ft. of heating surface, or the total radiation in square feet divided by 90 gives the boiler horse-power required.

Steam Drums.—Many of the boilers shown in connection with hot-water heating can be adapted for low-pressure steam. When the space at the top of such boilers is not sufficiently commodious, steam drums can be fixed immediately over the boilers to provide the requisite amount of space. These drums communicate with the boilers by passages at a number of points.

A sectional cast-iron boiler, the "Bundy Jewel", is shown in fig. 924. The upper portion of the boiler is deeply corrugated to increase the direct heating surface. The flames and heated gases, after coming in contact with the surfaces over the fire, pass down a double flue to the outlet. This boiler is made in a number of sizes rated to supply from 175 to 700 sq. ft. of radiation.

The vertical wrought-iron boiler (fig. 925) is occasionally used for heating work, but more generally for generating high-pressure steam. This boiler

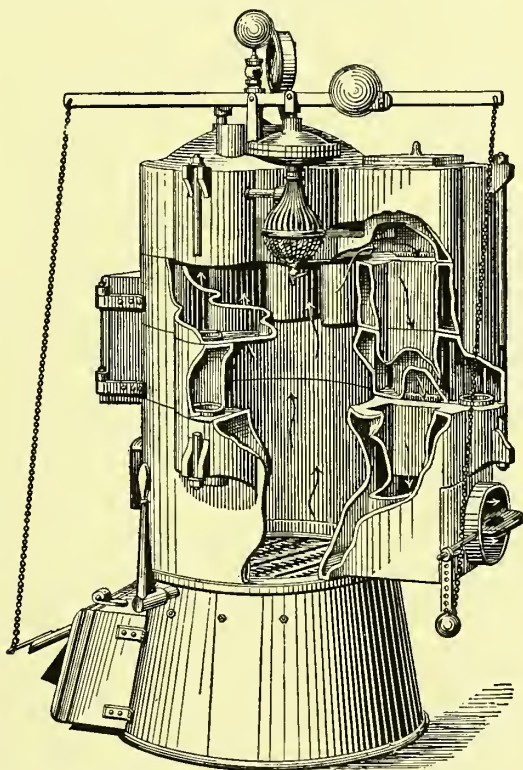


Fig. 924.—The "Bundy Jewel" Low-pressure Steam Boiler

pressure steam boilers is the automatic draught regulator, which is shown fixed in position in figs. 924 and 926 and in section in fig. 927. These fittings usually control two draught doors, one regulating the supply of air to the furnace, and the other serving as a check damper by admitting air into the chimney without first passing it through the fire. They generally contain a rubber diaphragm fixed between two special castings. A pipe which transmits the steam pressure is connected with the chamber A, fig. 927; when the rubber diaphragm B is raised, the lever C closes and opens the doors to which the chains D and E are attached. This regulator can be worked at any low pressure by simply adjusting the weight W on the lever. The water contained in the trap G should be sufficient in volume to protect the rubber diaphragm from

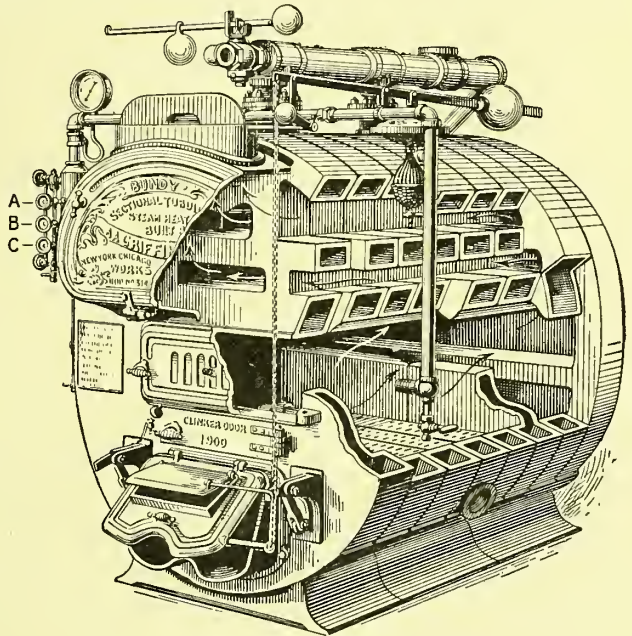


Fig. 926. —The "Bundy Tubular" Boiler

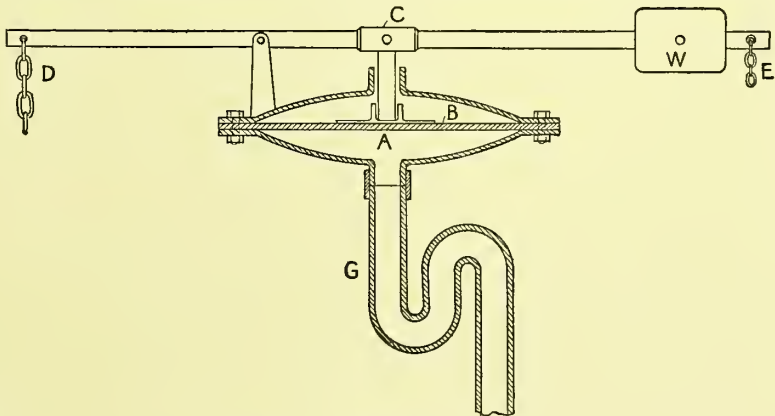


Fig. 927. —Automatic Draught Regulator

the destructive action of the steam. If the fire is fierce, and generates more steam than the apparatus can condense, the steam pressure will immediately rise and check the draught; but if insufficient steam is generated, the pressure falls and the draught is accelerated by the admittance of more air.

Water Gauges.—The American boilermakers provide a water column to their boilers, to which the water gauge is attached. This fitting is shown in position on the boiler in fig. 926. To the water columns are usually fixed three try cocks, lettered A, B, and C, which are used to determine whether the water gauge shows a true water line or not. One of the cocks is fixed

above the water line, another below it, and the other on a level with the mean water line.

Water columns are sometimes provided with floats which open a small steam valve, to which a whistle is attached.

When the level of the

water has reached a certain point, the valve opens and an alarm is given.

Automatic feeders can be fitted to a boiler to maintain the water level in places where the water of condensation is not wholly returned to the boiler. These appliances often consist of a compartment which contains a lever and float to regulate the admittance of water. The automatic feeder (fig. 928) is fixed in a position so that its centre corresponds with the water

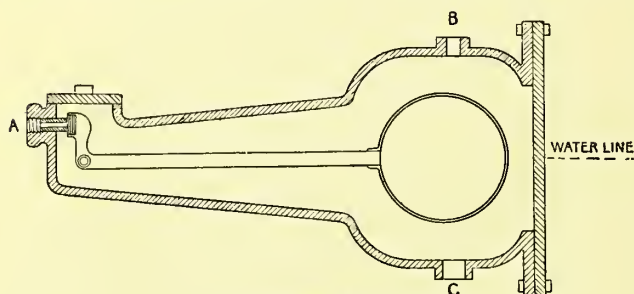


Fig. 928.—Automatic Feeder

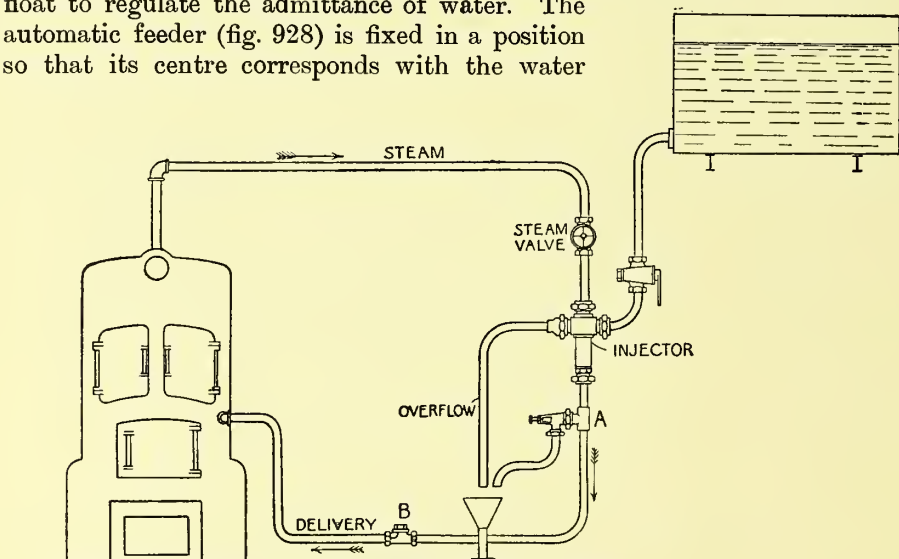


Fig. 929.—Holden & Brooks's Injector

line required. The water supply is connected to the inlet valve A, and the water pressure must exceed that of the steam or the appliance will not work. The connections B and C are joined with the boiler above and below the water line respectively. It is advisable to put strainers on the inlet connections to prevent any rust or sediment from gaining access to the valves and causing them to leak. Where water is supplied directly to

the feeders from a high-pressure main, the inlet orifices must be very small in order that the valves may close readily.

Injectors.—In places where the water authorities do not allow a direct connection between a steam boiler and a town's main, and where sufficient pressure cannot be obtained by the elevation of the feed cistern, an injector (fig. 929) or pump may be required to feed the boiler. Special injectors are made for low-pressure heating apparatus; and where cisterns can be fixed as shown, they will work with steam at 2 lb. pressure and less. Injectors are useful where lifting steam traps are used to return the water of condensation to the feed cisterns. On the delivery pipe to the boiler (fig. 929) a relief valve *A* is fixed, which is used when starting the injector; *B* is a non-return valve.

Injectors can also be used where they are submerged in tanks a little below the boilers; but under such conditions the height to which the water can be raised is very limited with low-pressure steam.

Steam traps are necessary appliances in many heating systems; they receive the water of condensation where it cannot gravitate back to the boilers, and prevent waste of steam. A trap discharging condensed water above its inlet is shown in fig. 917, and others in figs. 934 and 935.

A very good steam trap, known as the "Lancaster", is illustrated by section and plan in fig. 930. Water is poured into the trap until it stands level with the outlet *B*, and the condensed water is admitted into it through the hollow lever *F*.

At the inlet is a loose disc valve *A*, which is opened and closed by a quick screw motion as the float *H* falls and rises. To the top of the float an adjustable air valve *N* is attached, to which is connected a tube *L*, which terminates near the orifice *C*. Assuming that the ball has fallen, the inlet valve will be open, and condensed water can enter the trap. So long as water only flows, the ball remains at the bottom, owing to its being full of water, which has entered through the orifice *C*. When steam makes its appearance, it collects in the upper part of the ball and gradually displaces the water from it until the ball is rendered buoyant, when it rises and shuts off the steam. The steam in the ball is gradually condensed, and water re-enters through the orifice *C* until the ball loses its buoyancy

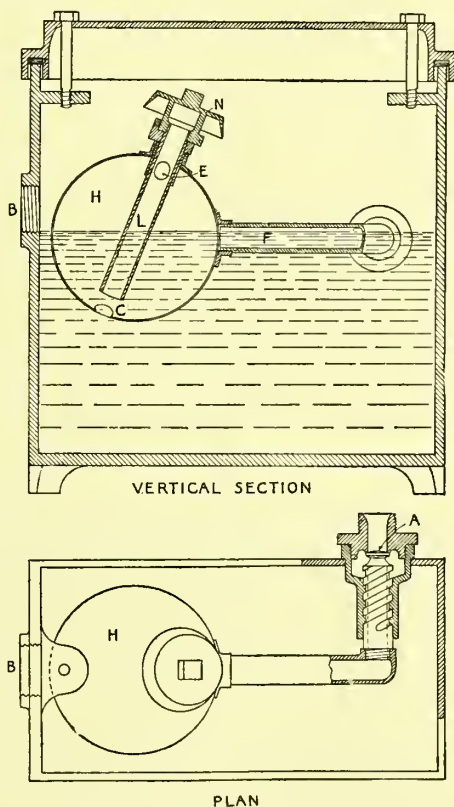


Fig. 930. —Lancaster & Tonge's Steam Trap

and again falls. If in the interval any water has accumulated at the inlet A, it is at once discharged; but if none is present, steam is at once admitted, when the water is again displaced, the ball rendered buoyant, and the steam inlet again closed. The small orifice E allows the escape of air, which would otherwise interfere with the working of the trap.

These traps are made with a cylindrical float, instead of a ball, where a more compact form of box trap is required; they also discharge the condensed water either below or above their outlets.

The height to which water can be raised above steam traps will depend upon the steam pressure at that point. Under the most favourable con-

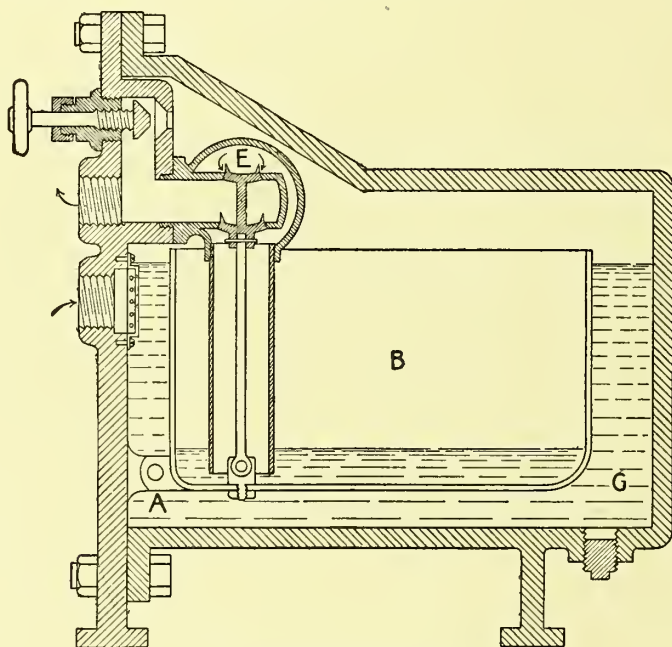


Fig. 931.—Kieley's Steam Trap

ditions water cannot be raised more than 2 ft. for each pound of steam pressure. When a steam trap is used for lifting water, a non-return valve should be fixed to its outgo to prevent water returning to the trap.

Fig. 931 illustrates Kieley's steam trap, made by the British Steam Specialties. It consists of a floating chamber B, which is pivoted at A to one end of the outer casing. Near the pivoted end of the inner chamber a rod in connection with a double-seated valve E is attached. This form of valve admits of a free and rapid discharge of water. The space G is first filled with water, and when the condensed water enters it overflows into the compartment B. While B is empty, or only partly filled, it is sufficiently buoyant to keep the valve closed; but when it is filled with water its front edge falls and opens the valve E. As the interior of this trap is always subjected to the full pressure of the steam, the contained water in B is forced up the inner tube to the outlet when

the valve is open. When the greater portion of the water has been dislodged from the chamber B, the valve is again closed. At the higher part of the trap a by-pass valve is fixed to discharge either air or steam, irrespective of the float-controlled valve E. This trap will also lift the condensed water above its outlet.

The box type of steam trap which has been shown cannot always be conveniently used, owing to the space it occupies. Fig. 932 shows a very compact trap, which is called the "Little Giant", and made by the Engineering Specialties Company. Its principal part is a circular metallic corrugated sealed capsule C, which contains a substance very sensitive to heat or cold. The inlet B is opened and closed by the contraction and expansion of the sealed capsule C. When steam is present the valve remains closed; but if water gathers, the capsule contracts and allows it to escape through the radial passages D, which are arranged at the base as shown. When adjusting this trap the whole casing is turned round on the inlet until the valve shuts off steam, and the jam nut E is then made secure.

Strainers (fig. 933) should be fixed to the inlets of steam traps to prevent chippings and rust getting under the valves.

Return Steam Traps.—Various forms of return steam traps are made to deliver condensed water back to the boiler from a tank or receiver without the aid of an injector or pump. Into the receiver A (fig. 934) the pipes B B deliver condensed water from two steam traps. The return trap D is fixed so that its lowest water

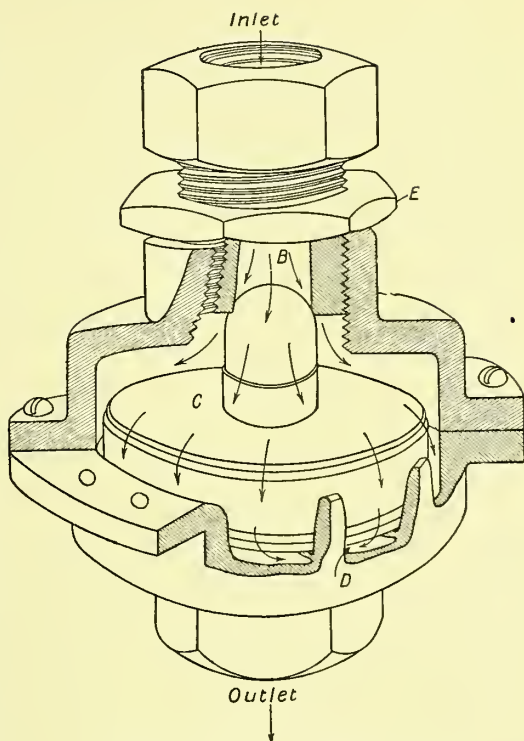


Fig. 932.—The "Little Giant" Steam Trap

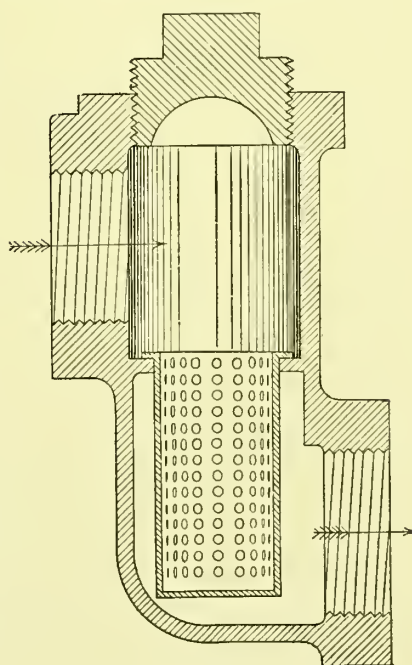


Fig. 933.—Strainer

level is about 3 ft. higher than the mean water line of the boiler. A cock operated by a float is fixed in D, to which the steam pipe S is connected. To start the return trap, it is filled with steam by opening the cock P for a short time. The non-return valve E in the pipe C prevents the steam from passing into the receiver A, and the non-return valve E in the pipe H prevents the water from the boiler entering the return trap when its internal pressure is reduced. The steam which has been admitted into D begins to condense, and a partial vacuum is created; the result is that water passes from the receiver into D. When sufficient water has entered the return trap, the float rises and the valve is opened and steam

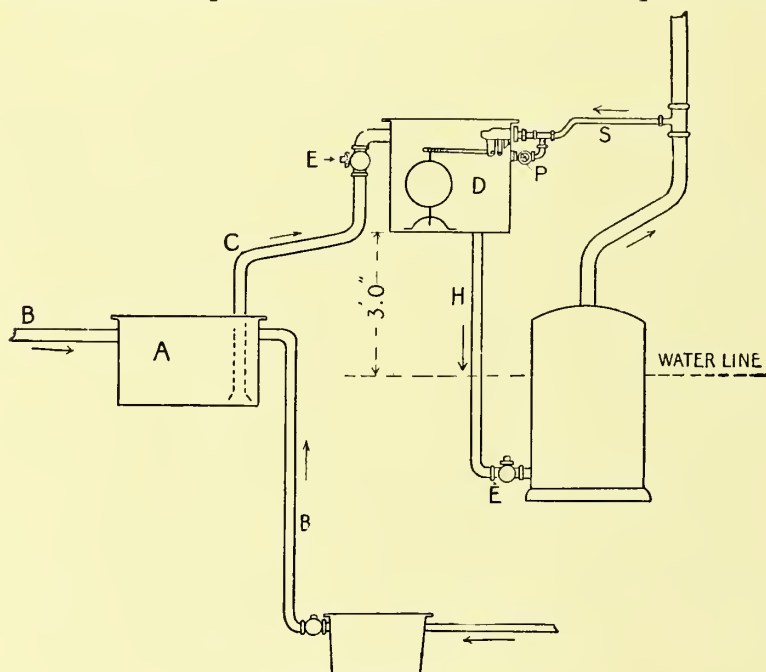


Fig. 934.—Return Steam Trap

admitted. At this period two equal forces from the boiler are acting upon the water in D, viz. the back pressure in the pipe H and the steam pressure on the surface of the water. As the return trap is fixed a certain height above the boiler water line, the pressure due to this, plus the steam pressure, overcomes the resistance in the pipe H, and the water from the return trap flows into the boiler until its level is sufficiently lowered to allow the float to fall and shut off the steam. As the return trap is left full of steam, condensation again takes place, and the cycle of operations is automatically repeated.

Another form of return trap, the "Bundy", is shown in fig. 935. The condensed water in this case is delivered from a receiver into the return trap by the pressure of steam in the receiver. The chamber T of the return trap is supported by a frame and two trunnions, which give it freedom to rise and fall inside the frame; the movement of T opens and

closes a valve *v*, which controls the supply of steam. The steam pressure in the receiver forces the condensed water up the pipe *P* past the non-return valve 1, and through a special fitting *F* into the chamber *T*. When this chamber is partly filled with water, its weight causes it to drop on to the frame at *H* and open the steam valve *v*. Steam is now admitted above the level of the water in *T* through the pipe *C*, and owing to the return trap being fixed above the water line of the boiler, and the unequal pressures which at this period exist, the water from *T* is enabled to flow through the non-return valve 2 and away to the boiler. Upon the chamber *T* being emptied, the weighted lever *L* raises it again to its filling position and closes the steam valve *v*. In connection with the steam

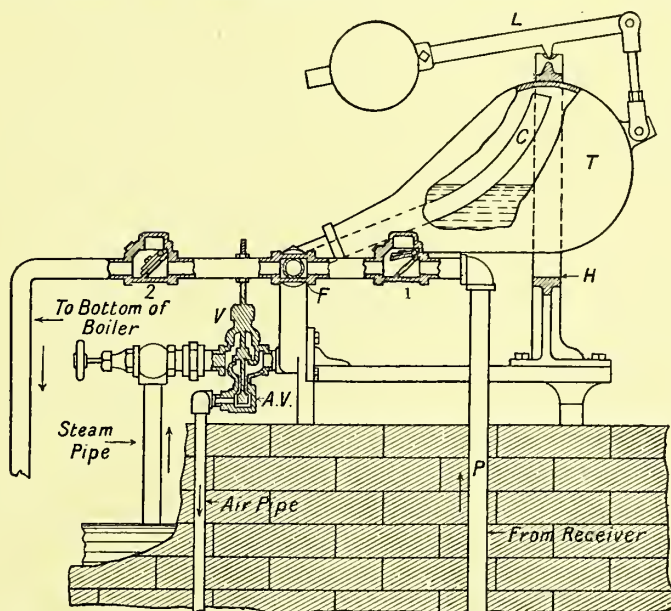


Fig. 935.—The "Bundy" Return Trap

valve a small air valve *A.V.* is arranged, which is opened when steam is turned off and allows air to escape during the filling of the chamber *T*. The air valve, however, is closed when the steam valve is opened, and prevents waste of steam.

Pump Governors.—For returning large volumes of condensed water, as in exhaust steam heating systems, automatic pump governors and receivers (fig. 936) are largely used. The pipes *PP* denote two returns, discharging into the receiver *R*, within which is a float, which operates the levers connected with the steam valve *v*, so that the speed of the pumps can be automatically adjusted to suit the rate of condensation. The loose motion at *E* allows the float to rise and fall within certain limits without altering the position of the valve. The speed of the pump is accelerated or retarded by the falling or rising of the float. The steam valve *v* does not shut off steam altogether, but allows sufficient to pass it in order to keep the pump just in motion. From the outlet *B* of the pump the condensed

water can be delivered directly to the boiler. A water gauge G is fixed

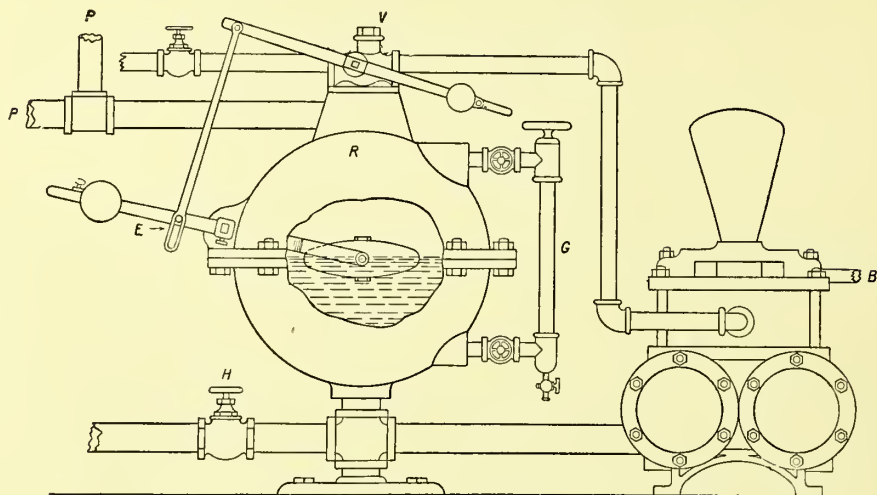


Fig. 936.—The British Specialties' Pump Governor and Receiver

upon the receiver R to indicate the height of the water inside, and the valve H serves the purpose of a blow-off.

Pumps.—A suitable pump to work in connection with these appliances is the Worthington "Duplex", which is really two pumps fixed side by side, the piston of one pump serving to operate the slide valve of the other. These pumps should be worked at a slow rate when they are used for pumping hot liquids.

Pressure-reducing Valves.—When steam is taken from a power boiler for low-pressure heating, a pressure-reducing valve is required. These appliances automatically reduce steam pressure, and when they are of good construction and properly adjusted they will maintain any low pressure desired. Fig. 937 shows a valve of this kind, the working parts of which are the equilibrium valve D, the diaphragm K, and the lever C, with adjustable weight E attached, at the bottom of the valve. When steam enters at A, it exerts its pressure equally upon both the upper and lower portions of the equilibrium valve D. If the weight E is removed, the valve D will fall and remain closed as shown, owing to its weight and the equal distribution of the steam pressure upon

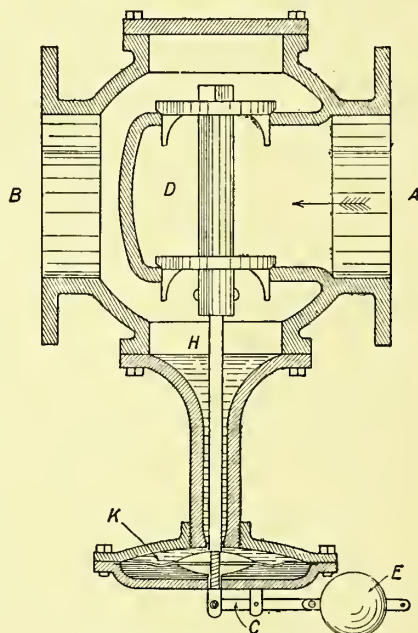


Fig. 937.—Pressure-reducing Valve

it. Suppose it is desired to reduce a pressure of 50 lb. on the inlet side A to 3 lb. on the outlet side B of the valve. This is done by adjusting the weight on the lever. If, now, the valve D has a force of 3 lb. over and above its own weight and friction, tending to open it, equilibrium is destroyed, and steam is allowed to pass through the valve to the outlet B. Unless some counteracting force came into operation, the valve D would be liable to remain open and let steam pass through with an undiminished pressure. The purpose of the diaphragm at the bottom of the valve is now explained, for if the pressure at B were to exceed its predetermined amount, the force exerted on the surface of the water H would depress the diaphragm K and close the valve D. Should the pressure in B tend to fall below that required, the valve is immediately opened by the weight E. By these means a practically uniform pressure is maintained.

The **safety valve** is necessary in connection with a steam boiler to relieve excess of pressure, and at least one safety valve should be fitted directly on the top of every boiler. The varieties in general use are of the dead-weight, spring-loaded, and lever types. Dead-weight valves are usually more satisfactory than the lever types, as the latter admit of easy overloading by a careless attendant. Spring-loaded safety valves are more generally used for power boilers than for heating purposes.

A safety valve should be sufficiently large to release the excess of pressure when the steam is shut off from the heating surfaces and when a big fire is burning; in other words, it should be able to release the whole of the steam generated without its exceeding a given pressure. Heating boilers are not constructed to withstand great pressures, and it is therefore necessary to provide adequate means for their safety.

The whole area of a safety valve is not effective for reducing pressure, and the Board of Trade, after a series of exhaustive experiments, now requires the areas of the valves to be proportional to the areas of the fire grates. The minimum diameter of safety valve for a power boiler is 2 in., but the minimum size for a heating system may be a little less than this.

The bearings of safety valves should be narrow, to lessen the risk of sticking, and they should be tested periodically, to see that they are in good working order. The extent to which a dead-weight safety valve should be loaded can be readily determined when its size and the blow-off pressure are known; thus the upper movable part and weights in pounds should equal the area of the orifice, multiplied by the blow-off pressure required.

CHAPTER XII

HEATING BY EXHAUST STEAM

Exhaust Steam.—In factories and public institutions, where power boilers are required for driving machinery, and where the steam engines are of the non-condensing type, exhaust steam is frequently utilized for heating the buildings wholly or in part. Where the exhaust steam is inadequate, it is

necessary to supplement it with live steam. The steam discharged from non-condensing engines contains approximately 80 per cent of the total heat of the steam, and the bulk of this may be utilized for warming buildings and heating feed water for the boilers.

An exhaust steam-heating plant is rather expensive to install, owing to the special fittings required, but the actual cost of heating is low, as heat is utilized that would otherwise be lost.

Back Pressure.—In order to overcome the resistance offered to exhaust steam in its passage through a system of pipes, it is necessary to put a little back pressure upon the engines. The amount necessary varies with the size of the system, but, as a rule, it need not exceed 2 to 3 lb. for

large installations, and may be less for small systems. The result of back pressure on an engine is to reduce its efficiency, or, in other words, a higher consumption of steam is necessary to drive it. It is essential, for economical working, to keep the back pressure on the engine as low as possible. The greatest back pressure is required when the installation is being charged with steam, as the air valves only permit the air to escape very slowly. When the air

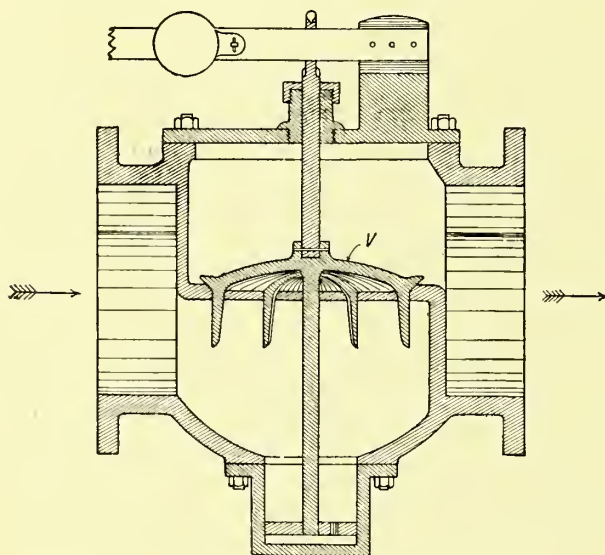


Fig. 938.—Back-pressure Valve

is once dislodged, a smaller back pressure, along with the partial vacuum which accompanies the condensation of steam, will be found sufficient to keep the apparatus thoroughly supplied, unless frictional resistances, due to either long or very small pipes, are great.

The back-pressure valve (fig. 938) is fixed in the exhaust pipe to divert the steam to the heating system. If the apparatus is not sufficiently large to condense the whole of the steam, the surplus escapes through the back-pressure valve to the open air, the valve *v* being steam-tight for all pressures less than that at which it is loaded to rise.

The oil or greasy matter used for lubricating the engine cylinder is present in the exhaust steam, and it is imperative that this grease be removed before the steam enters a heating system, as the effect of grease in radiators is to reduce the value of their heating surfaces.

Exhaust steam is freed from grease before it enters a heating system by being passed through a grease separator or extractor. These extractors are constructed in a variety of forms, but to be effective they require to be of a

fairly large size, in order that the steam may pass through them with a low velocity. They do not abstract every particle of grease, but good extractors allow very little to escape them. Fig. 939 shows a grease extractor in which the steam, on its passage to the outlet, comes in contact with a series of tubes, upon which the greasy matter is deposited; this then trickles down the tubes and falls into the chamber R. A valve *v* can be fixed to the chamber, and can either be regulated to drain away the greasy matter without permitting the escape of steam, or be opened periodically. The glass column *c* indicates the height of the liquid in the separator, and also aids in the adjustment of the valve. In some cases the valve is dispensed with and a steam trap used instead.

If the grease separator is small, the exhaust steam should be delivered first into a closed tank in connection with the separator to prevent sudden fluctuations of pressure. Some such provision is necessary to form a reserve and cushion, owing to the radiating surfaces requiring a fairly constant supply of steam, and the steam from the engine not being discharged in a continuous stream.

The common types of air valves, as previously stated, allow air to enter the radiators and pipes upon the apparatus cooling down, and this air must be displaced before the heating surfaces can be rendered effective.

A new type of air valve, known as the "Norwall" automatic air and vacuum valve, is illustrated in fig. 940. The object of this combination is to effect the discharge of air, and prevent its readmission into the heating system through the air valves. The working of the lower part, which effects the discharge of air, is explained in connection with fig. 923. The vacuum or upper part of the valve (fig. 940) is as follows:—The top valve *P* is attached by means of a cross bar to a bridge *T*, resting on the rod *s*, which in turn is attached to the diaphragm *Q*. The valve *P* is made to engage the upper seat by its own weight, and its function is to prevent air returning into the heating system from that source. To the upper part of the inlet connection a small tube *R* is attached, which communicates directly between

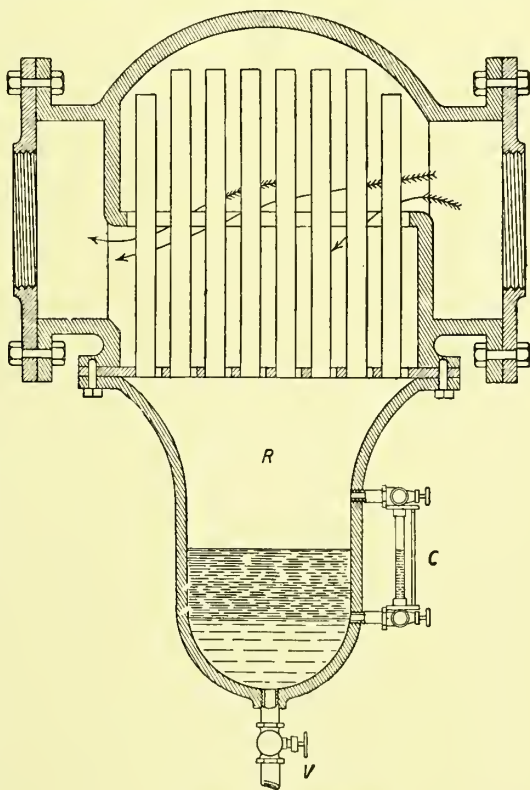


Fig. 939.—Grease Extractor

the heating system and the diaphragm. The rod *S*, on which is screwed both a flange and a lock nut, is fastened to the diaphragm. The flange nut passes through a hole in the bridge *T*, which is attached to the valve *P*. This connection is clearly shown in part elevation. When the pressure in the system reaches 1 lb., the diaphragm is forced up by the pressure transmitted through the tube *R*, and the valve *P* is unseated by the bridge *T* being raised. If air is present, the float *D* will have fallen and will permit it to escape. When the pressure in the system falls below 1 lb., the diaphragm reacts, and the valve *P* reseats itself.

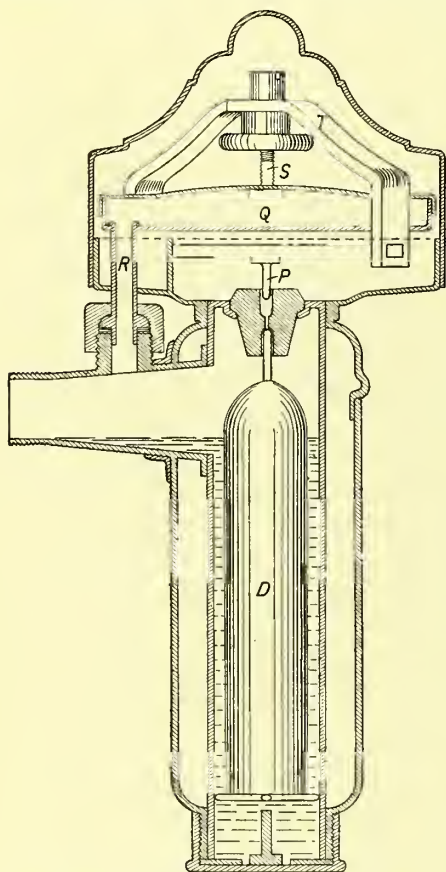


Fig. 940.—The "Norwall" Air and Vacuum Valve

A reliable air valve, constructed on a similar principle to fig. 940, would no doubt be a great advantage when fixed on all the radiators, coils, and pipes of an exhaust steam-heating system, for after the whole installation had cooled down, a partial vacuum would be formed, which would help (providing it is preserved) to fill the system when steam is turned into it.

In order to make such valves as fig. 940 successful in operation, it would be absolutely necessary to keep all the steam valves in good order, and have their stuffing-boxes tightly packed to prevent air entering there and destroying the vacuum formed. Under any conditions there would be a little difficulty in preserving a partial vacuum for any great length of time.

The water of condensation requires to be dealt with, and usually it is preferable to collect it in a suitable tank or receiver and pump it back to the boiler. It should, however, be raised to a high temperature before it

is delivered into the boiler, either by passing it through a feed-water heater or economizer. The question of dealing with condensed water in exhaust-steam systems is an important one, as it involves a large capital cost. Pumps and pump governors are expensive items, and so are many forms of return traps which are used in low-pressure live-steam heating.

In many districts where the water supply contains certain impurities, there is little choice as regards the best means of dealing with the water of condensation, whilst in others the following particulars might be ascertained before a decision is made:—(a) Suitability of water for raising steam; (b)

probable amount of condensation and its intrinsic value; (c) capital cost of special appliances for dealing with water of condensation, and interest and depreciation allowance.

The arrangement of the pipes in exhaust heating is the same as that for low-pressure steam heating, but the overhead system is considered to be the best for either low or high buildings. If, however, this system is not suited to the case under consideration, any other low-pressure method of piping can be adopted.

Fig. 941 shows a small exhaust-steam installation, arranged on the

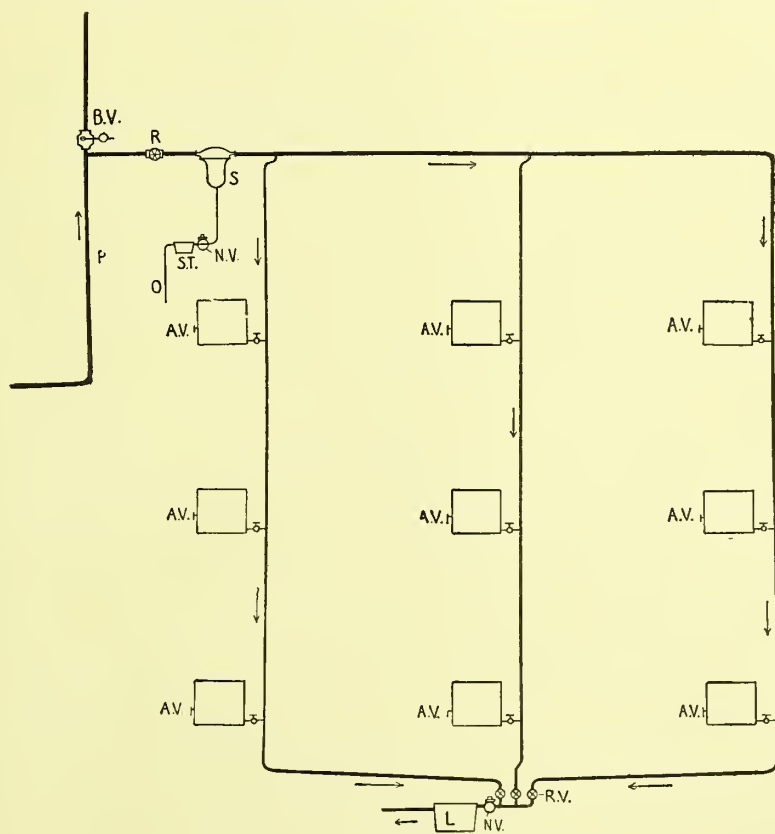


Fig. 941.—Exhaust-steam Heating Apparatus

overhead principle. The radiators are shown fixed in position, to which are attached combined air-and-vacuum valves ΔV . On the engine-exhaust pipe P a back-pressure valve $B V$ is fixed to divert the steam into the heating system. The grease separator S is situated near the back-pressure valve at the highest part of the system. The drain pipe from the separator discharges into a steam trap $S T$, from which the liquid matter is conveyed by the outlet pipe O to a suitable point of discharge. The stop cock R is for shutting off steam from the heating system, while the non-return valves $N V$ aid in preserving a partial vacuum in the system when the engines are not

running. The condensed water is drained into a receiver L, from which it can be pumped back either directly to the boiler or to the boiler feed tank. The valves R^V and similar valves fixed at the heads of branches serve to regulate the flow of steam through each branch-pipe.

A combined system of live and exhaust steam heating is illustrated in fig. 942. In this case either exhaust or live steam can be used separately, or both may be used together where sufficient exhaust steam is not available. The live-steam pipe U comes directly from a high-pressure

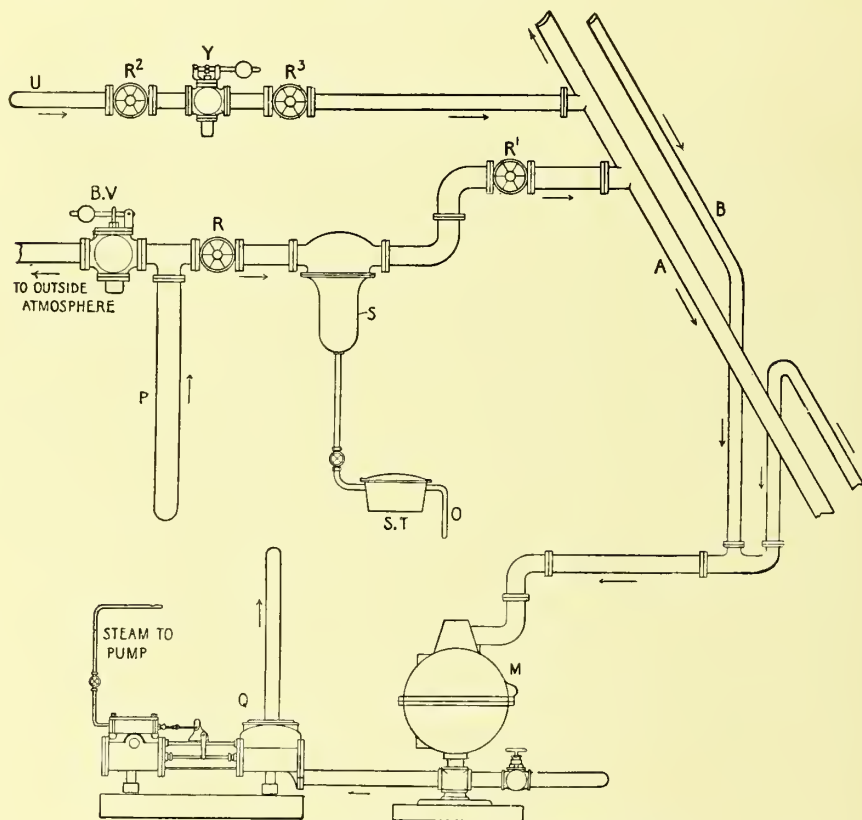


Fig. 942.—Combined System of Live and Exhaust Steam Heating

boiler, and the steam is lowered to the desired pressure by the pressure-reducing valve Y . The valves R^2 and R^3 on the same pipe are for shutting off steam from the reducing valve, in order that it may be adjusted or repaired at any time without shutting off the steam from the whole system. A steam valve R^1 is provided to prevent live steam passing to the exhaust pipe when only live steam is being used. A non-return valve could also be used in conjunction with the valve R^1 if it is thought desirable. The steam-heating main is indicated by A and the return main by B . The receiver M intercepts the condensed water, which is returned by the pump Q to the boiler. The mechanism in connection with the receiver M is omitted, as

well as the automatically controlled steam-supply valve. As in fig. 941, *P* denotes the exhaust pipe, *BV* the back-pressure valve, *R* the steam valve, *S* the grease extractor, and *ST* the steam trap with outlet *O*.

CHAPTER XIII

STEAM HEATING AT ATMOSPHERIC PRESSURE

The low-pressure systems of steam heating cannot be considered perfect, because the temperature of the heating surfaces does not admit of modulation, the steam being either full on or off. These systems are also subject to "air-binding" and "water-hammer". In a system of heating where the steam in the heating surfaces does not exceed the pressure of the atmosphere, these disadvantages can be overcome to a great extent.

In systems of steam heating at atmospheric pressure the steam has a small pressure before it enters the heating surfaces, but after it is admitted to them its pressure is immediately reduced. This method of steam heating is extensively used in some of the Continental countries, but is not common in this country.

The amount of steam admitted to any heating surface is controlled by a combined throttle and steam valve. The throttle part of the valve is simply a screw which protrudes into the inlet passage of the valve, so that the area of the passage can be contracted. The throttle valve is adjusted by the engineer who installs the system, and it is so regulated that it will pass only as much steam as the radiator will properly condense, when the thermometer records a given outside temperature. The steam or radiator valve proper is controlled by the occupant, who may regulate the degree of heat as desired. These valves are of various patterns, and many of them have a graduated index plate attached to show the extent to which the valve is opened.

The return risers and mains are open to the atmosphere. In order to prevent the escape of steam into the atmosphere from any heating surface various means have been devised. One method is to adjust the throttle valve so that it will admit the required amount of steam, and no more, when the radiator valve is turned full on. This mode of regulation is not always satisfactory, as such precision of adjustment on the inlet side of a valve cannot be readily obtained. The amount of steam a radiator or other surface will condense in a given time is not constant throughout the day; hence waste of steam must occasionally take place, unless the radiator valves are also adjusted to meet the changed conditions. Another method of preventing waste of steam is to fix a small steam trap to the outlet of each radiator. Reliable traps small enough for the purpose are not, however, easily obtained. The most satisfactory method of overcoming the difficulty is the introduction of special valves on the outlets of the heating surfaces. These valves are of two classes, viz.: (*a*) those which admit of

mechanical adjustment; (b) those which are automatically controlled. When these are used air valves are not required on the radiators, as the air can escape through the outlet connections to the atmosphere. In order to facilitate the displacement of air, it is desirable that the steam should enter the radiators at the top.

The water of condensation cannot be returned directly to the boiler; so it is first intercepted by a tank, which is fixed at a height above the boiler to suit the working pressure of the latter. The tank performs the function of a safety valve, and also receives water from the boiler when its working pressure is exceeded. The usual steam pressure of the boiler in this system is about $2\frac{1}{2}$ lb. per square inch, and the surface of the water in the tank must be sufficiently high above the water line of the boiler to equal this pressure. For the case given the height between the water levels would be approximately 6 ft. Fig. 943 shows that it is necessary to fix the boiler at a very low point, in order that the tank can be at an elevation to permit all the water of condensation to drain to it. No radiator for a boiler pressure of $2\frac{1}{2}$ lb. could be fixed much nearer than 7 ft. above the water line of the boiler, or 1 ft. above that of the tank.

The steam pipes may be smaller than those for an ordinary low-pressure system, owing to the facts that a greater drop in steam pressure can be allowed in the branches, and that steam can be passed through the pipes at higher velocities. It has been stated that 40 ft. of radiation can be supplied by a pipe $\frac{1}{4}$ in. in diameter. This is quite possible when short vertical copper branches are used, but for systems in which iron pipes are used a branch to supply 40 ft. of radiation under ordinary conditions would be $\frac{1}{2}$ in. in diameter, although the area of the passage through the valve itself might be restricted to less than that of a tube $\frac{1}{4}$ in. in diameter.

A method of arranging the pipes is shown in fig. 943. The steam main is arranged in a similar way to other systems, and should have a fall from the highest point of about 1 in 100. When the main is getting too low, it can be jumped up as at A. To relieve the condensed water from a riser or pocket, a dip B can be formed and joined with the return main. The dip must be deep enough to withstand slight fluctuations of the steam pressure; for a steam pressure of $2\frac{1}{2}$ lb. the dip should be about 7 ft. deep to prevent the water being forced out. Under most conditions there will probably be no difficulty in making a dip of the required depth, but if for some reason it cannot be done, a suitable steam trap can be fixed, providing that there is sufficient space between the pipes. A steam trap of course would relieve the water of condensation at such a point; but it would be much more costly than a dipped pipe, and not so satisfactory. The inlet and outlet connections of six radiators in fig. 943 are shown on the same side, and very often this mode of connecting is the most convenient. From the top of each riser return an air pipe is taken which terminates in the outside atmosphere; several air pipes may be connected together as shown. The return pipes are open to the atmosphere both at the head of the system and in the tank near the boiler; this arrangement permits the condensed water to drain easily from the pipes.

Fig. 943 shows the connections between the boiler and tank. The

former should be provided with the usual trimmings. The steam main is not provided with a steam cock; neither must there be a non-return valve on the return pipe R from the tank. The water to the boiler can be supplied directly from the town's main, or, where this is not permissible, it can be fed from a cistern in the usual way. A damper regulator is abso-

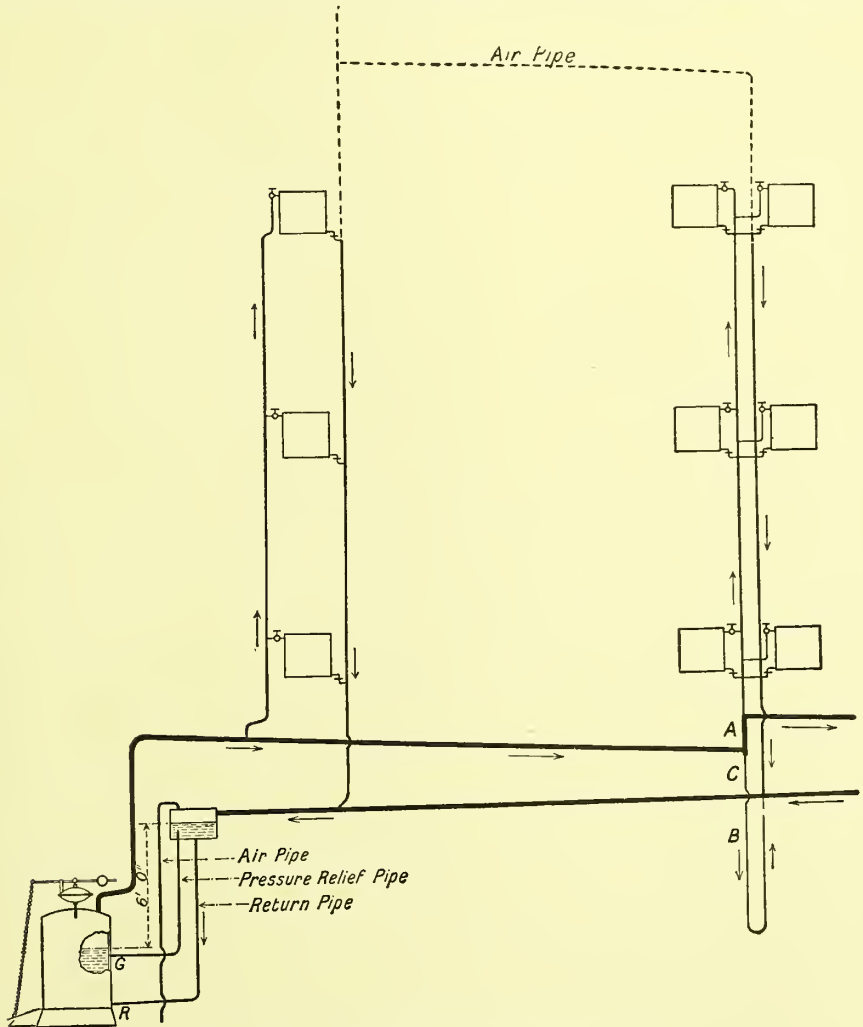


Fig. 943.—Apparatus for Steam at Atmospheric Pressure

lutely necessary in order that the steam pressure may be kept as constant as possible. As already stated, the height between the water levels of tank and boiler is governed by the steam pressure. Should the steam pressure be exceeded before the regulator can act, or by its failing to act, the water line of the boiler would be depressed and the water forced back into the tank until the level G is reached, when the steam would escape to the atmosphere from that point and afford the necessary relief. A safety

valve, loaded according to the working pressure of the boiler, would provide additional protection against danger from excess of pressure.

The volume of water contained in the expansion tank up to the normal water line should not greatly exceed that contained in a depth of $1\frac{3}{4}$ in. in the boiler, and the pipe G should join the boiler $1\frac{3}{4}$ in. below the mean water line. If the evaporation of water $\frac{1}{2}$ in. deep in the boiler is sufficient to fill the apparatus with steam, the maximum variation of the water line of the boiler under these conditions will be 4 in., that is, between the points when the apparatus is cold, and when there is an excess of pressure which causes the steam to escape. Upon the system cooling down, the water from the tank would pass back into the boiler and raise the water line. Properly proportioned boilers and expansion tanks are necessary to prevent the former being flooded, which would cause trouble and inconvenience when generating steam.

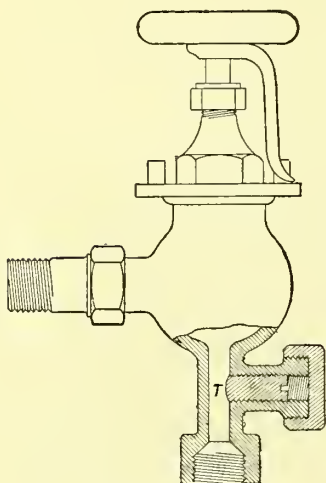


Fig. 944. —Radiator Valve

A special pattern of radiator valve is illustrated in fig. 944. At the inlet the throttling screw T can be adjusted by the fitter so that the valve will supply the necessary amount of steam, and when that is done the cap can be replaced. This valve has a quick action, being opened to the full by half a turn.

The sizes of radiator valves and connections are: Up to 75 ft. of radiation, $\frac{1}{2}$ in. in diameter, and from 75 to 150 ft. of radiation, $\frac{3}{4}$ in.

Outlet regulators, which are fixed in connection with radiators to permit of the escape of air and condensed water, are shown in fig. 945. In No. 1, by turning a movable slotted hollow cylinder A, the slot or aperture is easily adjusted to suit the rate of condensation. This form of regulation is really the contracting of the outlet until it is just large enough to pass away air and water of condensation without loss of steam. Sunde & Co's regulator (No. 2) belongs to the automatic class, and contains a composition ball, which floats in the chamber B. When the rate of condensation exceeds a certain amount, the condensed water collects in the chamber B, raises the float and effects its escape.

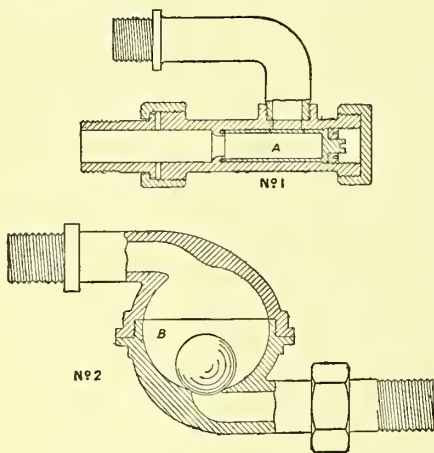


Fig. 945. —Outlet Regulators

contains a composition ball, which floats in the chamber B. When the rate of condensation exceeds a certain amount, the condensed water collects in the chamber B, raises the float and effects its escape.

TABLE XXVI.—APPROXIMATE SIZES OF MAINS AND RETURNS FOR STEAM HEATING SYSTEMS, WHERE THE RETURNS ARE OPEN TO THE ATMOSPHERE

Steam Main Diameter in Inches.	Returns.		Radiation in Square Feet.	Steam Main Diameter in Inches.	Returns.		Radiation in Square Feet.
	Vertical.	Horizontal.			Vertical.	Horizontal.	
$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	60	$2\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{2}$	1300
$\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	110	3	$1\frac{1}{2}$	2	2000
1	$\frac{3}{4}$	$\frac{3}{4}$	200	4	2	$2\frac{1}{2}$	4500
$1\frac{1}{4}$	$\frac{3}{4}$	1	280	5	$2\frac{1}{2}$	3	7000
$1\frac{1}{2}$	1	$1\frac{1}{4}$	450	6	$2\frac{1}{2}$	4	10000
2	$1\frac{1}{4}$	$1\frac{1}{2}$	750	7	3	5	16000

CHAPTER XIV

VACUUM SYSTEMS OF STEAM HEATING

Vacuum systems of heating by exhaust or live steam, or both together, are designed to remove air more effectually from radiators and other heating surfaces, and to accelerate the flow of steam to such surfaces, as well as to increase their heating value. In these systems the air is extracted from the pipes, whilst in other systems of steam heating the air is expelled by the pressure of the steam. When all air is removed from radiators their heating value is proportionately increased; thus a radiator which is supplied with low-pressure steam at (say) 4 lb. pressure, and which emits 1.6 B.T.U. per degree difference of temperature per hour per square foot of surface, would have that value increased to about 1.7 B.T.U. if the air were thoroughly removed. The temperature of the steam in a vacuum system should not be much less than 212° F. In a good vacuum system, where exhaust steam is used, practically no back pressure is placed upon the engine.

Fig. 946 shows the vacuum system of heating patented by Mr. Warren Webster of America, the licensees in this country being The Atmospheric Steam Heating Company, Ltd. A pump is used for extracting the air from the heating surfaces and for returning the water of condensation. To the radiators, and also in certain places in the steam mains, automatic air and water relief valves (often termed *thermostatic valves*) are fixed. Every automatic valve is connected with the return pipes, and is therefore in direct communication with the exhaust pump. The return pipes are always in a state of partial vacuum, and the air and condensed water are rapidly withdrawn; the steam in consequence flows freely through the mains to supply the heating surfaces. The thermostatic valves prevent the escape of steam into the return pipes by closing when steam comes in contact with the expanding medium inside them.

When commencing to heat up a building where this vacuum system is installed, the pump is first started, and as the thermostatic valves are open in the absence of steam, the air is exhausted from the pipes and heating surfaces, and when steam is admitted it readily supplies the vacuum.

In comparing the sizes of pipes required for a vacuum and those needed for a low-pressure system of heating, the difference in the sizes of the return mains will be found to be the most pronounced.

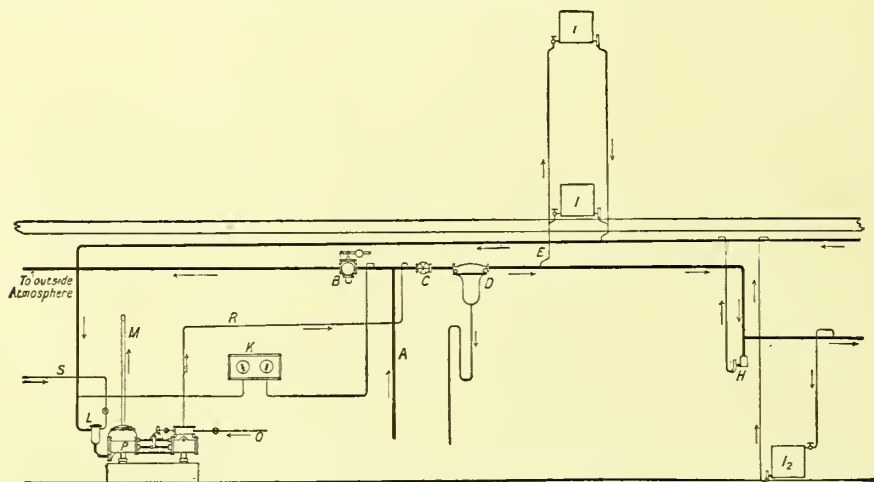


Fig. 946. — Webster's Vacuum System of Steam Heating

The temperature of the heating surfaces can be regulated by the steam valves in a vacuum system, whilst this cannot be done in ordinary low-pressure and exhaust systems of heating. The amount of heating surface to do a specific amount of work can be found by formula (8), and the temperature of the steam will depend upon the extent of the vacuum within the surfaces. The following table gives the measurement of vacuum in inches of mercury, and the corresponding temperature at which water boils:—

TABLE XXVII

Inches of Vacuum.	Water boils at Degrees F.	Inches of Vacuum.	Water boils at Degrees F.	Inches of Vacuum.	Water boils at Degrees F.
0	212	8	196·7	16	175·8
1	210·3	9	194·5	17	172·6
2	208·4	10	192·2	18	169
3	206·8	11	189·7	19	165·3
4	204·8	12	187·3	20	161·2
5	202·9	13	184·6	21	156·7
6	200·9	14	181·3	22	151·9
7	199	15	178·9	23	146·5

The extent of the vacuum required for a system will depend on the

arrangement of the pipes and the size of the installation. When a main return is fixed in such a position that the water of condensation must be raised to it, the vacuum must necessarily be greater than where the condensed water can flow by gravity into it.

In the system shown in fig. 946 exhaust steam only is used, which passes from an engine through the exhaust pipe A. The back-pressure valve B is set to open when the steam pressure exceeds $\frac{1}{4}$ lb. per square inch. This valve is chiefly necessary to prevent air from being drawn into the system from the atmosphere when a partial vacuum is established. An ordinary steam valve is fixed at C to shut off steam from the heating system when it is not required. The exhaust steam, before entering any of the distributing pipes, passes through the separator D to remove any particles of fatty matter. A small riser E is taken directly from the top of the steam main to supply the two highest radiators, but for risers $1\frac{1}{2}$ in. in diameter and over, or where it is first necessary to run a length of horizontal pipe in connection with a riser, a drip pocket should be formed to receive the condensed water; to the drip pocket an automatic valve must be fixed, which in turn must be joined with the main return. The radiators are shown fixed in position with the necessary steam valve and thermostatic valve attached to each. The radiator I_2 is at a low point, but the condensed water is easily removed from it, owing to the partial vacuum in the main return.

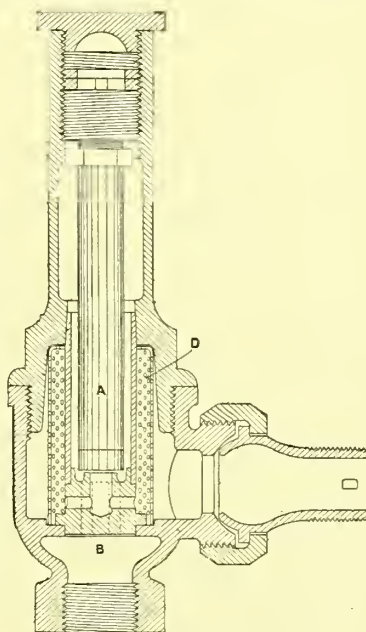


Fig. 947.—Thermostatic Valve

Two compound gauges, K, are shown fixed to the system, one being connected with the exhaust steam main and the other with the main return, so that either pressure or vacuum is shown.

To prevent rust or gritty matter from entering and damaging the pump, the condensed water is first passed through a strainer at the condenser L. From the pump P the water is discharged through the pipe M to the boiler. The steam supply to the pump is by the pipe O, and the exhaust from the pump by the pipe R, which discharges into the engine exhaust near the steam valve C. A water-supply pipe S is attached to the condenser L, in order that water can be admitted as occasion requires. When the continuity of the line of the steam pipe is broken by a sudden rise or drop, a pocket is formed in which the condensed water can collect, as shown at H. Steam traps are not essential in this system, and the pipes can be dipped without interfering with the working of the system.

The thermostatic valve, fixed to the outlets of radiators, for dealing with condensed water and air, in the Atmospheric Heating Company's

system, is illustrated in fig. 947. The valve operates by the expansion and contraction of a composition plug A, which opens and closes a central passage in the outlet B; it is also constructed with several small passages which permit of small quantities of condensed water being removed when the central outlet is closed. A gauze screen D surrounds the plug A, and intercepts any foreign matter which would tend to upset the working of the valve.

The automatic valve (fig. 948) can be used for discharging large quantities of condensed water. The inlet A is connected to the part to be drained, and, when water is absent, the outlet B is closed by the valve C, which is connected by a tubular rod H to the piston I. Upon the rod H a copper float D rises and falls, which closes and opens a small valve E.

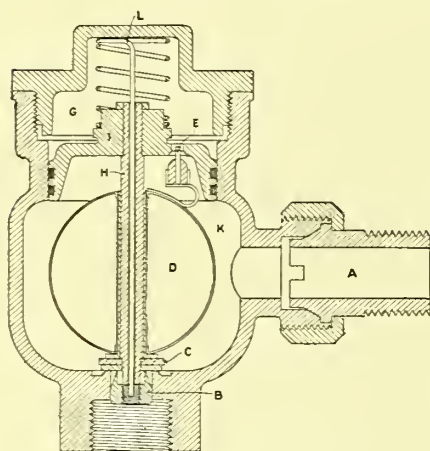


Fig. 948.—Automatic Valve

When the large valve C is closed, the small valve E remains open and allows the escape of air into the chamber G, and through the tubular rod H to the outlet B, which is connected with the vacuum return pipe. Upon water collecting in the lower part of the valve, the float D rises and closes the air valve E. The closing of E causes the chamber G to be in a state of partial vacuum, and as differential pressure is set up between the compartments G and K, the piston I is raised, the valve C opened, and the accumulated water discharged. A spiral spring L is shown fixed between the upper screw cap of the valve and the piston I, and one

end of this spring passes through the rod H in order that the air passage may be kept clear.

In buildings where exhaust steam is available for heating, and where it is necessary to keep the heating apparatus operative when the engine is stopped, live steam can be introduced into the heating system during the interval by regulating the supply through an ordinary steam valve. If, however, the volume of steam admitted is in excess of that which the apparatus will condense, steam will be wasted through the exhaust pipe, unless a stop valve, similar to that at C, fig. 946, is first closed. If such a valve is used a safety valve would require to be fixed, and regulated to blow off when the pressure in the apparatus had reached (say) 2 to 5 lb. per sq. in. In large installations, where live steam in addition to the whole of the exhaust steam is required, the amount of the former is usually controlled by an automatic steam valve.

The sizes of radiator connections are: Up to 40 sq. ft. of radiation, $\frac{3}{4}$ in. in diameter; from 40 to 80 sq. ft. of radiation, 1 in. in diameter; and from 80 to 150 sq. ft. of radiation, $1\frac{1}{4}$ in. in diameter. The connections of outlet automatic valves are $\frac{1}{2}$ in. in diameter.

TABLE XXVIII.—SIZES OF PIPE AND RADIATOR SURFACES IN THE VACUUM SYSTEM OF STEAM HEATING

Diameter Steam Main in Inches.	Distance from Boiler or Engine in Feet.							Diameter Return Main in Inches.
	100	200	400	600	1000	1500	2000	
	Radiation in Square Feet.							
$\frac{3}{4}$	40	30	20					$\frac{3}{4}$
1	60	43	30	25	20			$\frac{3}{4}$
$1\frac{1}{4}$	120	86	60	50	40			$\frac{3}{4}$
$1\frac{1}{2}$	200	142	100	82	64	40		$\frac{3}{4}$
2	480	340	240	197	153	130	100	1
$2\frac{1}{2}$	880	625	440	360	281	238	200	$1\frac{1}{4}$
3	1,500	1,065	750	615	480	408	340	$1\frac{1}{2}$
4	3,200	2,272	1,600	1,312	1,024	870	727	$1\frac{1}{2}$
5	6,200	4,400	3,100	2,542	1,984	1,686	1,408	2
6	10,000	7,100	5,000	4,100	3,200	2,718	2,272	$2\frac{1}{2}$
7	15,000	10,650	7,500	6,150	4,800	4,011	3,408	3
8	21,600	15,336	10,800	8,856	6,912	5,579	4,907	3

CHAPTER XV

HEATING BUILDINGS WITH CALORIFIERS

Advantages of the System.—In buildings where live steam is available, and it is thought desirable to warm such buildings by low-pressure hot water, the steam can be utilized for heating the water by the aid of a calorifier. When hot-water boilers are used for heating a number of detached buildings, such as the blocks or pavilions of hospitals, work-houses, and large schools, it is necessary in many cases to have a separate boiler for each building. When calorifiers are used, one boiler house only is required, so that the labour entailed by stoking is reduced to a minimum, and the calorifiers can be fixed in situations where it would be impossible to fix boilers.

Disadvantages.—Although calorifiers are very convenient for warming such buildings, they are not always economical, if steam has to be specially generated to supply them. Their chief disadvantages are: (a) High cost of steam boiler to supply them; (b) Loss of heat due to condensation by the transmission of steam through long pipes, and increased fuel consumption in consequence; (c) Expenditure involved either by the loss of the condensed water or by its return to the boiler.

The difference in cost of heating a series of detached buildings with hot-water boilers and calorifiers will largely depend upon circumstances. If little expense is involved in providing suitable places for the boilers, several hot-water boilers may be cheaper to install and work than one

or two high-pressure steam boilers and a number of calorifiers. On the other hand, where the cost of constructing several boiler pits would be heavy, steam boilers and calorifiers may be less expensive and more satisfactory.

The systems of piping in connection with calorifiers are precisely the same as those where hot-water boilers are used, and the sizes of pipes for equal quantities of heating surface are also the same; a calorifier simply takes the place of a boiler.

The most common type of calorifier or steam heater is a cylindrical vessel containing a coiled pipe through which steam passes. The steam upon condensing gives up its latent heat, which is transmitted to the water surrounding the coil.

The amount of heat transmitted through steam tubes surrounded by water varies with the temperature or pressure of the steam, the initial temperature of the water, the arrangement of the tubes, and the internal diffusion of the steam at or near the surface; but very little reliable information is available. An experiment is given in Box's *Practical Treatise of Heat*, where a coiled pipe 138 ft. long and 1.34 in. diameter was fixed in a vessel containing 880 lb. of water at 46° F. The coil contained 48 sq. ft. of surface, and was supplied by steam at 274° F., or 30 lb. gauge pressure. After steam had been turned on 4 minutes, the water was raised to 212° F. The amount of heat transmitted

through each square foot of tube in one minute was $\frac{880 \times (212 - 46)}{4 \times 48}$

= 761 B.T.U. The result would have been higher per square foot of surface per minute had the length of the tube been shorter. A portion of such a long tube would be ineffective, as it could not be properly supplied with steam. Some time ago it was a common practice to increase the area of the heating surface inside a calorifier or steam heater, by adding to the length of the coil, and this practice was chiefly responsible for the ineffectiveness of such heaters.

Modern calorifiers have their tubes arranged to transmit as much heat as possible per unit area of surface in unit time, and a course adopted to attain this end is to provide short tortuous or circuitous passages through which the steam must flow. A small coil of tube is more effective than an equal length of straight tube whether horizontally or vertically arranged. Plain vertical tubes supplied with steam in the ordinary way transmit heat more slowly than other forms, owing to the film of water inside them not spreading over their whole surfaces.

Rowe's tube, which is largely used for calorifiers, has two series of corrugations made alternately at right angles to each other. The efficiency of the tube is due to the interrupted course the steam takes when flowing through it. To test the efficiency of this invention a length of indented copper tube containing 1 sq. ft. of surface was surrounded by 11 gal. (i.e. 110 lb.) of water at 42° F. Steam was supplied to the tube at 62 lb. pressure, and in five and a half minutes it raised the water to 212° F. A plain copper tube of the same area and under the same conditions raised the water to 212° F. in eleven minutes. The average amount of

heat transmitted per minute through 1 sq. ft. of surface of the plain tube equals $\frac{110 \times (212 - 42)}{11} = 1700$ B.T.U., whilst the indented tube

gives $\frac{110 \times (212 - 42)}{5\frac{1}{2}} = 3400$ B.T.U. The tube in each case was arranged vertically. The difference between the two tests would not have been so great if the plain tube had been more favourably arranged.

Plain tubes are more effective when arranged in small coils. The length of pipe in each coil should not greatly exceed 150 diameters, as the tail end of a long tube answers the purpose of a drain pipe only, and is almost useless for transmitting heat. Where a large amount of tube surface is required inside a heater, a number of separate coils should be arranged or a series of vertical tubes may be used, whose ends are joined to steam spaces, and treated as in fig. 949.

In **Andrews and Cameron's Calorifier** (fig. 949) the principle is introduced of circulating either water or steam through the tubes by the aid of an injector, to render their heating surfaces more effective. Vertical tubes are arranged around an enlarged centre tube, which has an injector fixed at the inlet end. Small chambers are formed at each end of the calorifier to receive the open ends of the tubes. High-pressure steam is admitted through the valve at the top of the calorifier, and passes through the injector and down the centre tube. The action of the injector causes the steam to circulate more thoroughly through the small tubes, as indicated by the arrows. The condensed water escapes through the valve at the bottom to a steam trap in the usual way. For evaporating water coils may be used in lieu of straight tubes, but an injector is arranged as well. The object of circulating the steam is to promote a thorough and continuous diffusion of the particles, and completely to cover the whole inner surface of the tubes with the water film.

A necessary attachment in connection with all calorifiers used for

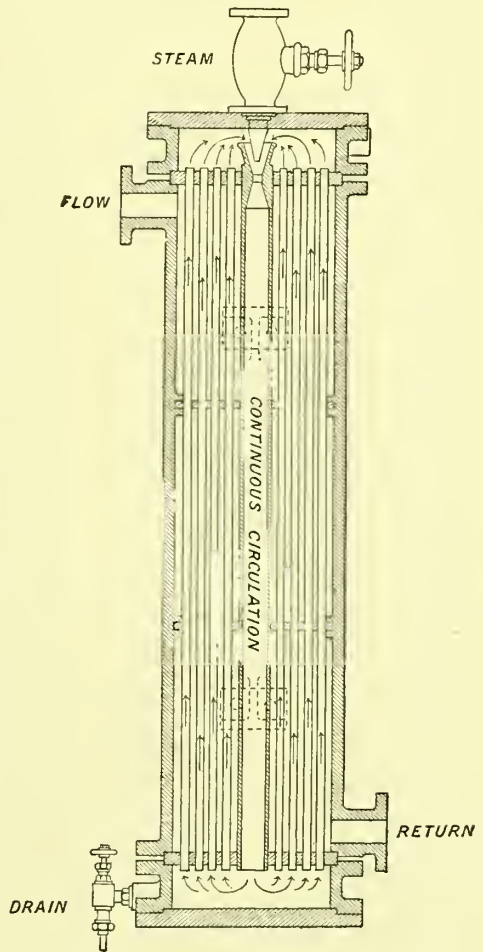


Fig. 949.—Calorifier with Vertical Tubes

heating purposes, is an **automatic valve** for controlling and shutting off the supply of steam when the water has reached a given temperature, in order to prevent overheating and waste of steam. J. Pyle & Co.'s automatic valve operates in connection with the steam trap which receives the condensed water from the steam heater. In Royle's automatic attachment the steam valve is opened and closed by the contraction and expansion of the body of the calorifier

CHAPTER XVI

THE RECK SYSTEM OF COMBINED STEAM AND HOT-WATER HEATING

The chief feature of this system, which was designed by Captain Reck of Copenhagen, is the mixture of steam and water in such a way that a vigorous circulation of the water is induced. The general arrangement is illustrated in Plate XLII, the principal parts being the boiler A, reheater B, condenser C, circulator D, and expansion tank E. The boiler is designed for low-pressure steam, and is fitted with the essential automatic draught regulator, by which the steam pressure is maintained from 2 to 5 lb., according to the size of the heating system. Where high-pressure steam is available, the boiler can be dispensed with, and a reducing valve used to give the steam pressure desired.

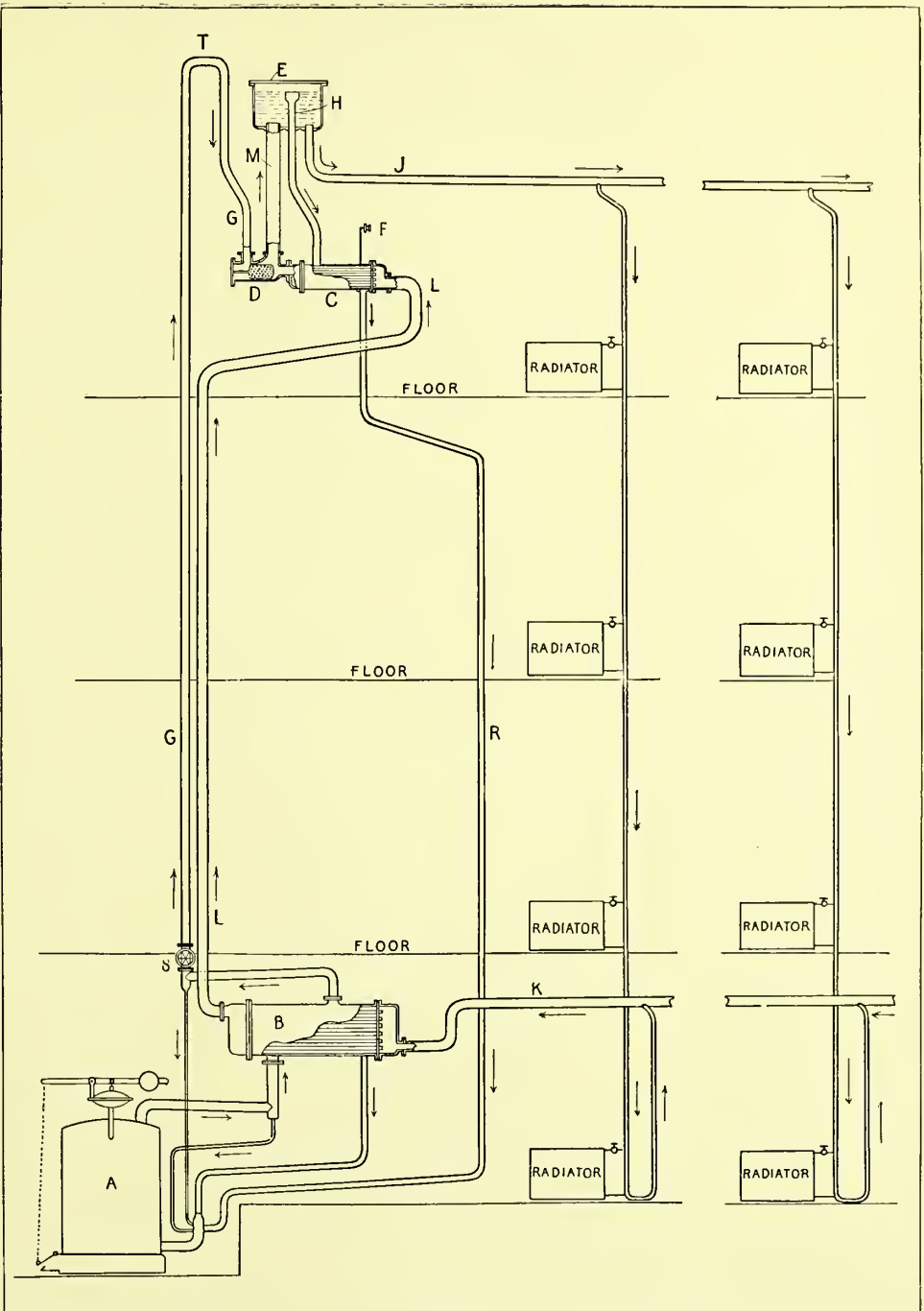
The **reheater B** consists of a cast-iron casing, which is filled with straight tubes of small diameter. The steam from the boiler or other source passes into the casing of the reheater or calorifier, and imparts heat to the water in its passage through the tubes. From the casing of the reheater B a steam pipe G is taken to the highest part of the apparatus, and joins the circulator D. For heating small buildings or separate floors the reheater can be discarded, and water can be heated by the circulator alone.

The **circulator D** is a small cast-iron box through which all the water in the system passes, and contains a gauze screen at its inlet for the admittance of steam. The purpose of the gauze is to admit steam into the water in the form of a fine spray, in order to obviate any cracking noise. The circulator must be fixed in an elevated position.

The **expansion tank E** serves to separate the steam from the water, and to accommodate the increased volume of water in the system when heated.

The function of the **condenser C** is to convert into water any steam that may pass from the space above the water surface in the expansion tank through the pipe H. The condenser is similar in construction to the reheater, but much smaller, and is fixed on the hot-water flow pipe L from the reheater, immediately in front of the circulator D. As the water flows from the reheater it passes through the condenser tubes, whilst any steam which passes through the pipe H is delivered into the casing of the condenser, and converted into water upon contact with the cooler surfaces.

By following the lines of piping the courses of the water and steam can be plainly seen. Starting at the reheater, the water rises through the pipe L



THE "RECK" SYSTEM: COMBINED STEAM AND HOT WATER

- | | |
|------------------------------|--|
| A, Boiler. | J, Flow Pipe to Radiators. |
| B, Reheater. | K, Return Pipe from Radiators. |
| C, Condenser. | L, Hot-Water Pipe to Condenser. |
| D, Circulator. | M, Hot-Water Pipe to Expansion Tank. |
| E, Expansion Tank. | R, Return Pipe from Condenser to Boiler. |
| F, Air-Valve from Condenser. | S, Stop-Cock. |
| G, Steam Pipe. | T, Automatic Valve. |
| H, Steam Pipe to Condenser. | |



and passes through the condenser into the circulator, from which it flows to the expansion tank through the pipe M. A pipe J is taken from the bottom of the expansion tank to supply the radiators with heated water, which is returned from the heating surfaces by the pipe K to the reheater B. The course of the steam is first through the casing of the reheater, thence by the pipe G to the circulator, where it mixes with the water. Any steam which is not condensed in passing through the water by way of the pipe M rises to the top of the expansion tank. The increase of water due to the continual condensation of steam overflows through the pipe H, along with any remaining steam, to the condenser, from which the former flows back by the pipe R to the boiler.

If a stop cock were fixed at S on the pipe G, and the steam turned off from the circulator, the system would work exactly like an ordinary system where only a calorifier was used. The water of course would rise from the circulator into the steam pipe, until it reached the same level as that in the expansion tank.

The reason for making the steam pipe higher than the expansion tank before it joins the circulator is to prevent the water flowing back from the expansion tank and flooding the boiler. On the top of the bend at T an **automatic valve** is attached, which opens in the absence of steam, and prevents the water from E being siphoned out when steam is turned off and condensation in the steam pipe takes place.

Accelerated Circulation.—When steam is admitted through the pipe G it will flow until it meets the column of water, and if its pressure is sufficiently great it will force the column of water back into the expansion tank. The height between the circulator and the expansion tank varies according to the size of the heating system and the kind of building; if this height is divided by 2, the necessary steam pressure for dislodging the water out of the steam pipe is obtained. Immediately the water is forced from the steam pipe the steam and water mix, and the action of the circulator will commence. Water and steam in combination are much lighter than water alone, and owing to the reduced density of the mixture it is rapidly dislodged by the colder and denser water in the return main. The mixture of steam and water in the pipe M is directly displaced by the water from the pipe L, which in turn is forced upwards by the heavier column of water between J and K. The lightness of the ascending column of water in the pipes L and M, together with the action of the circulator, make the velocity of the circulation throughout the whole system about four times that in an ordinary low-pressure system fixed under similar conditions and with the same length of pipe. The accelerated velocity due to the action of the circulator is perhaps more easily grasped by considering the case of an injector arranged in connection with a flow pipe. The effect of the injector would be to induce a rapid upward current in the flow pipe, and this would in like manner affect the remainder of the system.

The Reck system in some respects resembles the heating of a building by calorifiers, but it differs in the utilization of a portion of the steam to increase the motion of the water in the pipes. The advantages derived from an accelerated circulation are: (a) smaller pipes can be used; (b) greater

freedom in arranging and fixing pipes; (c) heat can be transmitted longer distances; (d) obstacles can be more easily overcome. Although the Reck system is a combined steam and hot-water one, steam cannot flow through the pipes into the radiators, owing to the pipe J being connected with the bottom of the expansion tank. The steam and water channels are separate, except at the circulator D, where the mixing action takes place.

The piping is arranged in various ways to suit different classes of buildings. Where the mains can be distributed both at the top and in the basement of a building, the one-pipe system (Plate XLII) can be conveniently installed. For buildings where it is necessary to fix both flow and return mains in the basement the two-pipe system (fig. 950) would be adopted.

One special feature of the Reck system is the ease with which the difficulties due to varying levels can be overcome. To show the extent to which a main pipe in the system can be dipped, the following particulars were kindly supplied to the writer by Messrs. Boyd & Sons of Paisley. "In a school home at an institute in Denmark, the main pipe travels about 150 ft. along the roof, drops down 25 ft. to the ground level, runs along 50 ft., rises 25 ft. again into the roof, and continues there for a further distance of 200 ft. The pipe therefore travels 450 ft., and contains a pocket 25 ft. deep and 50 ft. long." Water could be circulated through a dip of the dimensions given in any ordinary system of hot-water heating by the aid of a pump, but some form of motive power would be necessary to work it, and this would be a continuous source of extra expense.

Fig. 950 shows how the pipes are arranged on the two-pipe system. The steam main from the boiler takes the usual course, first to the reheater, thence to the circulator, and afterwards to the expansion tank. The hot-water pipe J is conducted from the expansion tank to the basement, along the basement ceiling, and the water returns by the pipe K to the reheater, from which the pipe L rises to the condenser C and circulator D. From the horizontal flow and return mains the risers supply the radiators on the different floors, one group only being shown. The lowest radiator is shown fixed beneath the mains, and although the system is a two-pipe one there is no difficulty in getting this radiator to heat. It may be thought that short-circuiting would take place as in an ordinary two-pipe system, but this is obviated to a great extent by the strong circulation induced by the circulator, the careful grading of the mains, and by fixing regulating cocks on the return connections to the radiators. In places where a large amount of heating surface is fixed below the reheater, the one-pipe system is better as shown in Plate XLII.

The expansion tank E is made proportional to the total capacity of the heating system, and when the apparatus is in use the water in the expansion tank should reach the top of the overflow H, while the boiler at the same time should show a normal water line. After the apparatus is charged with water, any loss or leakage is indicated by the lowering of the water level in the boiler, as any loss of water must lower the level of that in the expansion tank, and before water of condensation can be returned to the boiler through the overflow H that loss must be made good from the boiler.

An air-escape pipe, with automatic valve attached, must be fixed on the top of the condenser to liberate any air that may accumulate at this part of the system.

The sizes of valves and branches to radiators in the Reck system are:

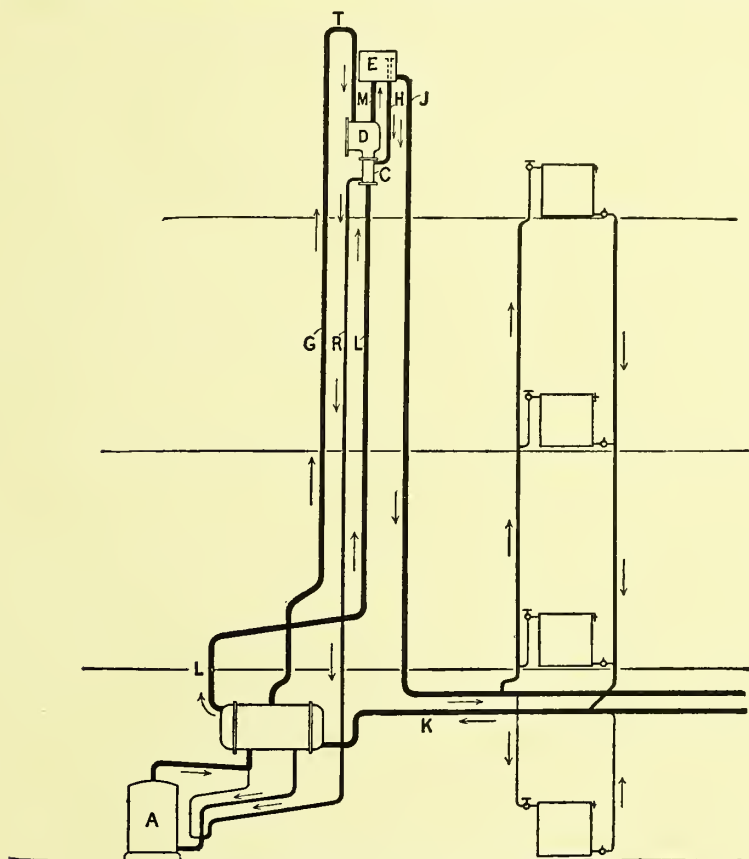


Fig. 950.—The Reck Apparatus: Two-pipe System

Up to 90 sq. ft. of radiation, $\frac{3}{8}$ in. in diam.; from 90 to 120 sq. ft., $\frac{1}{2}$ in., and over 120 sq. ft., $\frac{3}{4}$ in.

TABLE XXIX.—APPROXIMATE RADIATING SURFACE SUPPLIED BY PIPES OF DIFFERENT SIZE (RECK SYSTEM).

Size of Main.	Radiation in Square Feet Approximate.	Size of Main.	Radiation in Square Feet Approximate.
1 in. diam.	240	2½ in. diam.	2890
1¼ " "	500	3 " "	4160
1½ " "	780	3½ " "	5600
2 " "	1540	4 " "	7280

CHAPTER XVII

GENERAL REMARKS ON LOW-PRESSURE HEATING SYSTEMS

Common Defects of Heating Systems.—Heating installations occasionally prove unsatisfactory. Now and again it is found that certain coils or radiators fail to heat, or, at most, only get lukewarm. In other cases the consumption of fuel is excessive for the amount of work done. After large rooms and buildings have been heated, draughts are sometimes experienced that were not noticed, or, at any rate, were not so pronounced before the heating apparatus was installed. Failures are chiefly caused by one or more of the following faults:—

1. Insufficient heating surface.
2. Boilers too small.
3. Chimneys too small, or having too much or too little draught.
4. Dirty flues.
5. Short-circuiting.
6. Air-locked pipes or radiators.
7. Pipes too small.
8. Water-hammer, or noise in pipes.

The conditions which a perfect heating apparatus should fulfil are as follows:—

(1) Possibility of uniting all the boiler power in one room to reduce labour in attendance.

(2) Quick regulation from some central point to meet the exigencies of the weather.

(3) The most distant radiator or other surface to be heated within a reasonable time.

(4) The temperature of an apartment to be regulated by adjusting the radiator valves.

(5) Automatic regulation of fuel consumption by boiler to prevent waste.

(6) Silent in action.

(7) No skilled attention required.

(8) Boilers should hold sufficient fuel for eight to ten hours.

(9) Not costly to install or expensive to maintain.

(10) Neat in appearance and safe in operation.

Very few heating installations (if any) will satisfy all these conditions, but a system can be selected that will satisfy the most important.

For heating dwelling houses and similar buildings **low-pressure hot water** is the most desirable, on account of its low cost to install and maintain, and the mildness of its heat. The particular system of piping to adopt will depend upon the kind of building, as already shown.

Steam heating is very suitable for factories, churches, and assembly rooms, and for use in connection with mechanical systems of ventilation. It is advantageous in many public buildings owing to the short time required for raising or lowering the temperature in the apparatus. For

places which are not regularly heated in frosty weather, steam is better than hot water owing to the reduced risk of the steam apparatus being frozen up. Generally speaking, the chief disadvantages of steam are, that the apparatus is more costly to install and maintain, and that the heat is fierce and dry. The latter disadvantage is greatly lessened when the steam is reduced to atmospheric pressure, and can be almost entirely removed in a vacuum system of steam heating. The temperature of the heating surfaces in low-pressure steam apparatus¹ cannot be controlled, but this drawback does not exist in atmospheric or vacuum systems of steam heating. For small installations steam is costly, and is not recommended unless the climatic conditions make its adoption desirable.

To heat **factories** it is often necessary to fix the heating surfaces overhead, on account of the floor space being occupied by machinery. The efficiency of the heating surfaces in such cases is only slightly impaired, as the revolving belting in connection with the machines prevents a very heated stratum of air accumulating near the ceilings. As steam is the usual heating agent in such places, the pipes may be more conveniently arranged, and less difficulty will be encountered in returning the water of condensation to the boiler, than where the heating surfaces are fixed on the floor. The heating surfaces may be either in the form of pipes, or, where a quantity of heat requires concentrating in a limited area, in the form of coils suspended from the ceilings.

For buildings erected on the pavilion or block system, and where the boiler power must be concentrated at one common centre, the separate parts can be heated by means of **Calorifiers**, or by the **Reck** or the **Vacuum system**. These three systems are similar in two respects, viz.: steam boilers are necessary, and the water of condensation in the majority of cases must be pumped back to the boilers.

CHAPTER XVIII

SWIMMING BATHS AND DRYING CLOSETS

The water of **swimming baths** is generally warmed either by low-pressure hot water or by steam.

When a **hot-water apparatus** is used the flow and return pipes may either be connected directly with the bath, or the water in the boiler may circulate through coils formed in the circulating pipes, and fixed in open recesses at the sides of the swimming bath. A simple arrangement of circulating water through a large bath is shown in fig. 951. This mode of heating large quantities of water through a small range of temperature, such as is required in swimming baths, is undoubtedly the cheapest where a special heating boiler must be provided. A circuit should be

¹Low-pressure steam is usually understood to be steam under 10 lb. gauge pressure. For heating buildings the pressure should not exceed 5 lb. per square inch, and a lower pressure is preferable.

arranged for each side of the bath, and, if the bath is long, branch flow pipes may with advantage enter the water at two or more points. The water in these baths is usually kept at a temperature of about 75° F., and in cold weather the water in the town's main is not much lower than 45° F. Thus for the conditions stated the water requires heating (75 - 45) = 30° every time a swimming bath is refilled in cold weather.

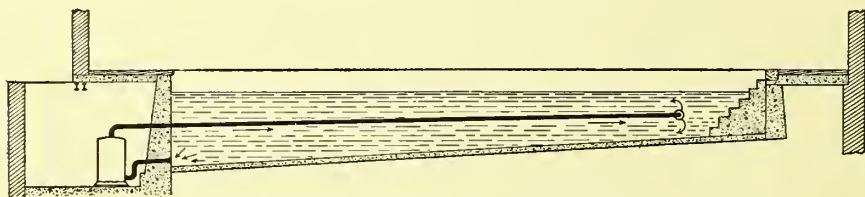


Fig. 951.—Swimming Bath with Water Circulation

The size of the boiler will be governed by the volume of water and the time allowed for heating it. The grate area can be calculated by the rule:—

$$A = \frac{10 G (P - T)}{w f c t} \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

Where A = area of grate in square feet.

„ G = volume of water in gallons.

„ P = temperature of water desired.

„ T = temperature of cold water in main.

„ w = weight in pounds of fuel consumed per square foot of grate per hour.

„ f = calorific value of coal per pound in B.T.U.

„ c = coefficient depending upon the kind of boiler.

„ t = time in hours allowed for heating the water.

The values of *c* are given in connection with formula 9, Chapter VI, and the value of *f* in Table XII, p. 121.

Example.—Find the size of a boiler for warming in six hours the water of a swimming pond which holds 24,000 gal. of water; temperature required, 75° F.; temperature of cold supply, 45° F.

Taking the values of *w*, *f*, and *c* at 12, 13,000, and 0·6 respectively, the grate area is readily obtained—

$$A = \frac{10 G (P - T)}{w f c t} = \frac{10 \times 24,000 \times (75 - 45)}{12 \times 13,000 \times 0.6 \times 6} = 12.82 \text{ sq. ft.}$$

If the heating of the water could be extended over a period of twelve hours, the area of the grate could be reduced by one-half, providing the other conditions are equal. Where a **high-pressure steam boiler** is provided for driving washing machinery, or for heating drying stoves, Turkish baths, &c., separate boilers for heating the water of swimming baths are not necessary or desirable, as the water can be warmed in the early hours of the morning before steam is required for other work.

Where steam is used, a good method is to introduce it into the water at one or more points through special **injectors**, and the pipes can be arranged

to create a circulation of the water throughout the bath when the injector is in use. In fig. 952 a large bath is heated by steam flowing through two injectors, which are fixed at the deep end. To each injector a pipe is connected from the shallow end of the bath, so that circulation can take place; the direction of the currents is shown by the arrows. For a small swimming pond one injector is sufficient, and the return connections can be fixed near it as shown in fig. 953. The better course would be to take the return to the injector from the other end, but where a bath is small, and the expense of making a subway round it is not desirable, the arrangement shown in fig. 953 will answer fairly well.

The rate at which the water is cooled in large baths is not great in the summer time, and if a Turkish bath adjoins, which is heated by steam,

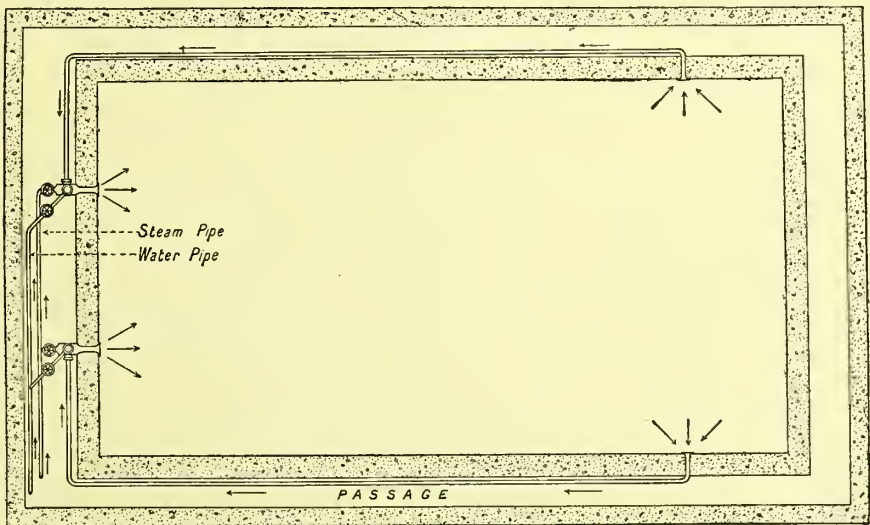


Fig. 952.—Swimming Bath with Two Steam Injectors and Water Circuits

the hot condensed water from the heaters, if discharged into the swimming bath, will often suffice to maintain the temperature required. Heat is lost in two ways: (*a*) by conduction through the walls and floor of the bath, (*b*) by convection or cold currents of air. The former source of loss is not very great, but the latter may be responsible for a reduction in temperature of 1° F. to 3° F. or more in one night in winter. In a bath with a capacity of 22,000 gal., the water of which falls $1\frac{1}{2}^{\circ}$ F. in one night, the total heat lost equals $22,000 \times 10 \times 1\frac{1}{2} = 330,000$ B.T.U. To renew this amount of heat about 40 lb. of coal would require to be burned in a good circulating boiler, or 291 lb. of steam at 75 lb. pressure must be introduced. This weight of steam does not include losses due to transmission through pipes.

Drying Rooms for Laundries.—For the artificial drying of clothes, hot water and steam are chiefly resorted to. Either exhaust or live steam may be used, but the suitability of exhaust steam will greatly depend upon the required temperature of the drying room. When this does not exceed 100° F., either hot water or exhaust steam can be used, but for higher

temperatures, and for quick drying, live steam at 10 lb. pressure is more suitable.

An excellent method of drying clothes is to arrange a number of **horses or racks** in connection with a chamber, so that they may be easily withdrawn. The racks may be formed of galvanized wrought-iron pipes which are secured to a face plate, the whole being carried upon wheels which run on iron rails. The rails are prolonged outside the drying chamber to a

distance equal to, or longer than, the racks themselves. The width of the racks varies according to the method adopted of arranging the heating surfaces. In drying rooms the radiant heat should be utilized as far as possible, and this can be done by arranging the heating surfaces in the form of coils, and fixing them a little above the floors between the racks; if the coils are arranged in this way, the projected or radiant heat will strike a larger surface of the fabrics which are being dried. A few years ago it was the general practice to fix the heating surfaces beneath iron gratings in the floor, but this method is not economical, as the radiant heat is lost, and additional heating surface is required.

It is essential that good **ventilation** be provided in a drying room, in order that moisture may be readily removed during the process of drying. The fresh air upon entry should be distributed as evenly as possible throughout the whole space, and the outlets may be connected with an extracting shaft. Where large quantities of water are evaporated during the drying process it is often necessary to fix an extracting fan in the outlet shaft; but a better plan is to force the air into the drying chamber, as the inflowing air is more equally distributed by this means.

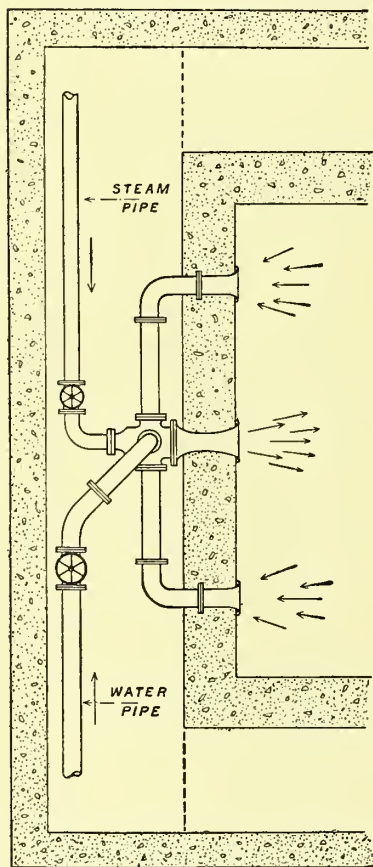


Fig. 953.—Swimming Bath with One Steam Injector

The most economical results will be obtained when the temperature is high, and the ventilation so adjusted that the air escapes in a nearly saturated state. In Box's *Treatise on Heat* the weight of vapour contained in 1 lb. of saturated air at 42° F. is given as .00561 lb., and at 112° F. .06253 lb. Thus if air is delivered to the drying closet in a saturated state at 42° F. and it escapes at the outlet saturated at 112° F., each pound of air in its passage through the drying closet would have taken up $.06253 - .00561 = .05692$ lb. or 398 grains of moisture. The higher the temperature at the outlet the greater the amount of moisture

which the air will hold. The temperature of a drying chamber, however, must not be raised to such a height that it will damage fabrics.

The amount of heating surface will be chiefly controlled by the temperature of the surfaces, the amount of moisture to be removed, the time allowed for the clothes to dry, and the nature and arrangement of the heating surfaces. The approximate amount of 4-in. pipe for small drying chambers per 1000 cu. ft. capacity is 175 ft. for live steam at 9 to 10 lb. pressure, and 280 ft. for exhaust steam and low-pressure hot water, the temperature of the water in the pipes being 180° F.

CHAPTER XIX

ENCrustATION AND CORROSION OF PIPES AND BOILERS

Encrustation.—Some kinds of water are very injurious to pipes and boilers, and where large quantities of such waters are used, some preliminary treatment is usually necessary.¹ Temporary hardness is due to the presence of carbonates of lime and magnesia, which produce deposits in boilers upon the water being heated near its boiling-point. Permanent hardness, which is due to sulphates, does not cause deposits in ordinary hot-water boilers, but does so in steam boilers, owing to the evaporation of water. Steam boilers thus reduce both temporary and permanent hardness. The deposit may be in the form of sludge, scale, or powder, according to the chemical composition of the salts which cause the hardness.

In ordinary hot-water heating apparatus where the water is not withdrawn from it, and in steam systems where the water of condensation is returned to the boilers, the accumulation of saline matter is not very rapid. When hard water is used the boilers should always be provided with waterways below the fire bars, and mud lids should also be fixed in order that any accumulation may be periodically removed.

The effects of scale in boilers are to impair the general efficiency of the heating surfaces, and if the scale is thick there is a danger of burning the plates and spoiling them. It has been stated that the presence of scale $\frac{1}{16}$ in. thick reduces the efficiency of the boiler by 15 per cent, $\frac{1}{8}$ in. thick 30 per cent, $\frac{1}{4}$ in. thick 50 per cent, and $\frac{1}{2}$ in. thick over 80 per cent, but these values do not represent facts, as a boiler is seldom scaled over all its surfaces. The surfaces mainly affected by deposit are those where very hot water cannot freely escape to the outlet, and where local currents are set up. If a portion of the direct heating surface of a boiler is covered with a film of scale, and its rate of heat transmission is reduced, the products of combustion will pass at a higher temperature to other surfaces, which in turn will transmit a greater amount of heat. Of course the efficiency of the boiler would be impaired, but not to the extent given by the above figures. A very thin film of scale inside a boiler may scarcely

¹ See Section V, Chapter XII.

affect the rate of heat transmission, as the resistance to the passage of heat is much greater on the fire side than on the water side of a boiler plate.

The corrosion of boilers is chiefly the result of acid waters, or of oxygen in the feed water. In some cases iron is so rapidly attacked that copper boilers must be used, or the acids must be neutralized by adding an alkali, such as soda ash. In steam heating systems the return pipes are often badly corroded, while the steam pipes are scarcely affected; this is owing to the return pipes carrying distilled water, the free oxygen combining with the iron of the pipes, and forming ferric oxide or rust. The rusting action is not equal, but the pipes are usually corroded in patches. The corrosion of pipes by acid waters in hot-water systems is often caused by the contained gas being given off from the water in the form of beads, and lodging upon their surfaces. Where the circulation is rapid there is less liability to this mode of corrosion, owing to the surfaces of the pipes being kept nearly free from the lodgment of gas.

Soft waters usually produce the most serious corrosion of pipes and boilers, but some of the hard waters are also troublesome. The acidity in water is often acquired by the water flowing over peaty ground, and by contact with decaying vegetable matter. Hard water, whose hardness is due to carbonates of lime and magnesia, has little corrosive effect upon iron pipes which convey hot water, owing to the precipitation of a protecting film of carbonate of lime upon their surfaces.

Large boilers can be protected to a great extent from corrosion by putting in them blocks of zinc. The zinc, however, is of little use unless good contact is made between it and the iron surfaces. The protective influence of zinc is also limited in its radius, and for this reason it is better to fix the zinc in places where corrosion has already begun, or is likely to take place.

CHAPTER XX

NON-CONDUCTING MATERIALS

Heat Losses.—The main pipes and boilers of hot-water and steam heating apparatus will lose a great amount of heat unless they are covered with some good form of insulating material. The heat losses from steam pipes are much greater than those from hot-water pipes, owing to the higher temperature of the former and the condensation of steam that takes place. The heat lost by low-pressure hot-water pipes is about two-thirds of that from low-pressure steam pipes. The loss of heat from a plain pipe which conveys low-pressure steam varies from 320 B.T.U. in still air to over 900 B.T.U. when the pipe is exposed to cold air currents, per square foot of surface per hour. The heat lost represents so much fuel consumed for no useful purpose.

The materials used for covering pipes are very varied, but one of the best for low-pressure apparatus is hair felt. For pipes which convey high-pressure steam, hair felt is not so suitable, owing to the destructive effect of high temperatures upon it, and the possibility of its charring. Air, when confined, makes an excellent non-conductor of heat, and this can be easily proved by comparing the amount of heat transmitted by (say) the surfaces of a hot-water cylinder which is exposed to view, with the amount of heat lost by the surfaces of a similar cylinder cased in. The term "non-conductor" is used in a relative sense, as there is no such thing as a perfect insulator. The best non-conducting materials allow a certain amount of heat to pass through them. Pipe and boiler coverings should be low in cost, easily applied, good insulators, and neat in appearance.

The following table gives the values of a series of tests on different pipe-covering materials by Mr. G. M. Brill, U.S.A. (Vide *Am. Soc. M.E.* 1895):—

TABLE XXX

Kind of Covering.	Thickness of Covering in Inches.	Ratio of Heat Lost Bare to Covered Pipe, Per Cent.	B.T.U. Transmitted per Hour per Square Foot per Degree Difference of Temperature.
Bare Pipe	—	100	2·70
Magnesium	1·25	14	·38
Mineral Wool	1·30	10	·28
Fire Felt (Asbestos)	1·30	18	·50
Manville Sectional	1·70	13	·35
Manville Sectional and Hair Felt	2·40	8	·21
Hair Felt	·82	15	·42
Fossil Meal	·75	32	·87

The *Manville Sectional* covering is composed of asbestos, sulphate of lime, paper, and a little silica; and the *Magnesium* covering of asbestos and carbonates of magnesium and lime.

The results of a more comprehensive series of tests made by Prof. Carpenter on various pipe coverings at Silby College, Cornell University, are given in Table XXXI.

The value of having boilers and mains covered with a suitable insulating material is more apparent where the saving on a 12-weeks coal bill is considered.

Example.—The exposed surfaces of boiler and main pipes of a steam-heating installation amounts to (say) 100 sq. ft. The average steam pressure is 9 lb. per square inch (238° F.), and the average air temperature to which the surfaces are exposed is 48° F.

The heat emitted from the unprotected surfaces is taken as 2 B.T.U. per degree difference of temperature per square foot of surface per hour.

The total heat lost by 100 sq. ft. of surface in 12 weeks for the conditions given, if the apparatus is in operation both day and night, equals

$$100 \times 2 \times (238 - 48) \times 2016 \text{ hours} = 76,608,000 \text{ B.T.U.}$$

Taking fuel with a calorific value of 12,000 B.T.U. per lb., and the average efficiency of the boiler at 60 per cent, the fuel consumed to supply the heat lost by the surfaces

$$= \frac{76,608,000}{7200} = 10,640 \text{ lb. or } 4\frac{3}{4} \text{ tons.}$$

If now the exposed boiler and pipe surfaces were protected with a good non-conducting material which has 80 per cent efficiency, the fuel consumption for heat losses would only be

$$\frac{4.75 \times 20}{100} = .95 \text{ ton or 19 cwts.}$$

Thus, in the example given, if the surfaces are properly protected a saving of 3 tons 16 cwt. of fuel is effected in a period of 12 weeks.

TABLE XXXI (PROF. CARPENTER)

Kind of Covering.	Relative Amount of Heat Transmitted.
	Per Cent.
Naked pipe	100
Two layers asbestos paper, 1 in. hair felt, and canvas cover ...	15.2
Two layers asbestos paper, 1 in. hair felt	17
Hair felt sectional covering, asbestos lined	18.6
One thickness asbestos board	59.4
Four thicknesses asbestos paper	50.3
Two layers asbestos paper	77.7
Wool felt, asbestos lined	23.1
Wool felt with air spaces, asbestos lined	19.7
Asbestos and sponge	18.8
Asbestos and wool felt	20.8
Magnesia, moulded, applied in plastic condition	22.4
Magnesia sectional	18.8
Mineral wool sectional	19.3
Rock wool, fibrous	20.3
Fossil meal, moulded, $\frac{3}{4}$ in. thick	29.7
Pipe painted with black asphaltum	105.5
Pipe painted with light drab lead paint	108.7
Glossy white paint	95.0

The tests given in Tables XXX and XXXI show somewhat similar results, but any little difference is doubtless due to the different conditions under which the two sets of experiments were carried out. The two series show generally the superiority of loose light materials when

compared with more compact substances. The efficiency of loose materials is due to the air which is contained in the interstices of the materials. Although hair felt ranks as a good non-conductor, it is not so easily and evenly applied when alone as some of the other coverings.

The effect of coating heating surfaces with paint is also shown in Table XXXI. Glossy white paint shows a diminished transmission of heat when compared with uncoated surfaces, whereas surfaces painted with light drab or black asphaltum paint show an increased transmission.

Accelerated Circulation in Low-pressure Hot-water Systems.—Much attention has been devoted recently to the problem of accelerating and controlling the circulation of the water in low-pressure heating systems, and several appliances are now being largely and successfully adopted.

One of the best-known systems is that patented by Messrs. G. N. Haden & Sons, which consists of a small mechanical propellor, known as the "Turbo" Accelerator, which is inserted in the return pipe near the boiler, and driven by electricity, petrol, or gas, as may be most convenient. The use of this appliance relieves the boiler entirely of the duty of circulating the water, and it can be so adjusted and controlled that the difficulties resulting from the length of run, friction, dips, and improper grading or proportion of pipes may be successfully overcome. The velocity of circulation can be varied to suit atmospheric conditions by retarding or accelerating the revolution of the propeller, so that when, for instance, the weather becomes suddenly cold the velocity of the circulation can be increased, the rooms therefore being heated more rapidly without resort to hard firing. The pipes used in this system may be considerably smaller in diameter than otherwise, and it is claimed that the cost of driving the accelerator is more than covered by the saving of fuel in the boiler.

A system of a different type, not depending on any mechanical device, is being installed by Messrs. Wontner-Smith, Gray, & Co., under licence from the patentees. In this case the accelerated circulation is due to the bubbles of ebullition which are released as soon as the temperature of the water in the boiler reaches about 100° F.

The flow pipe from the boiler is connected to a collecting box placed immediately over it, and from the bottom of this box the main flow pipes are taken, and the return pipes are connected to the boiler in the usual way. As soon as the bubbles of ebullition are released they rise immediately into the upper part of the box, and as they accumulate they create a differential pressure between the flow and return pipes, thus causing a rapid circulation. Automatic means are provided to prevent the accumulation of steam or bubbles from interrupting the circulation or making it noisy.

